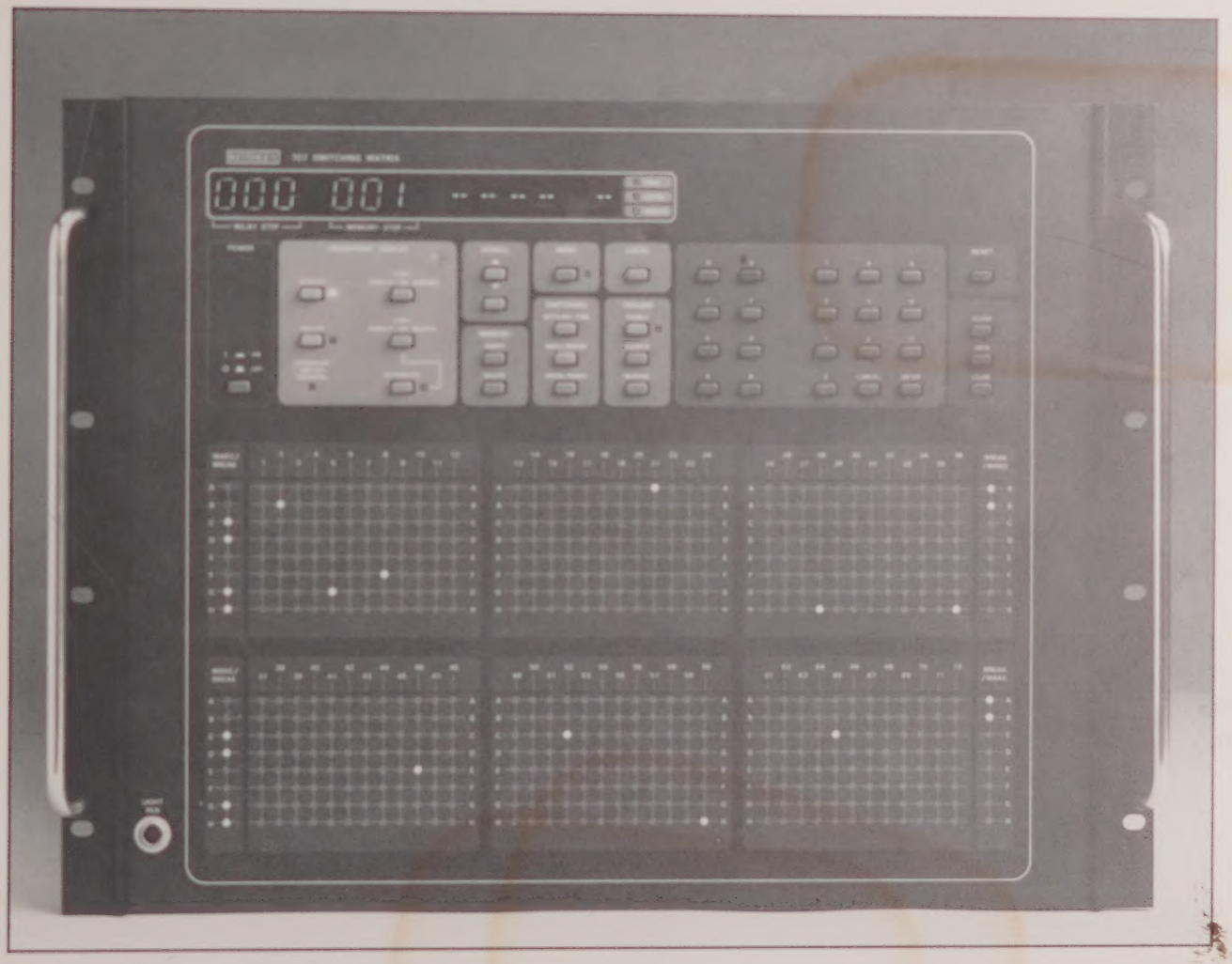
KEITHLEY

Model 707 Switching Matrix Instruction Manual



Contains Operating and Servicing Information

Model 707/Switching Matrix

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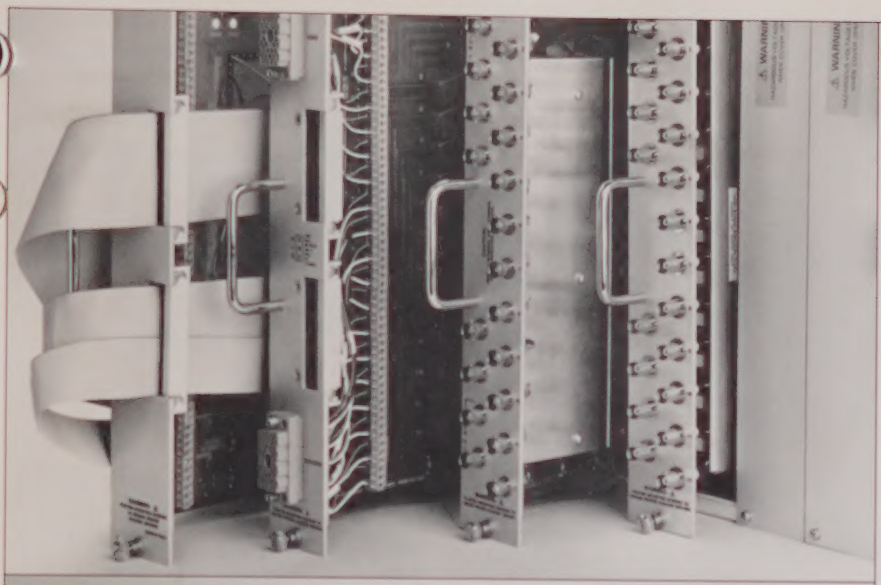
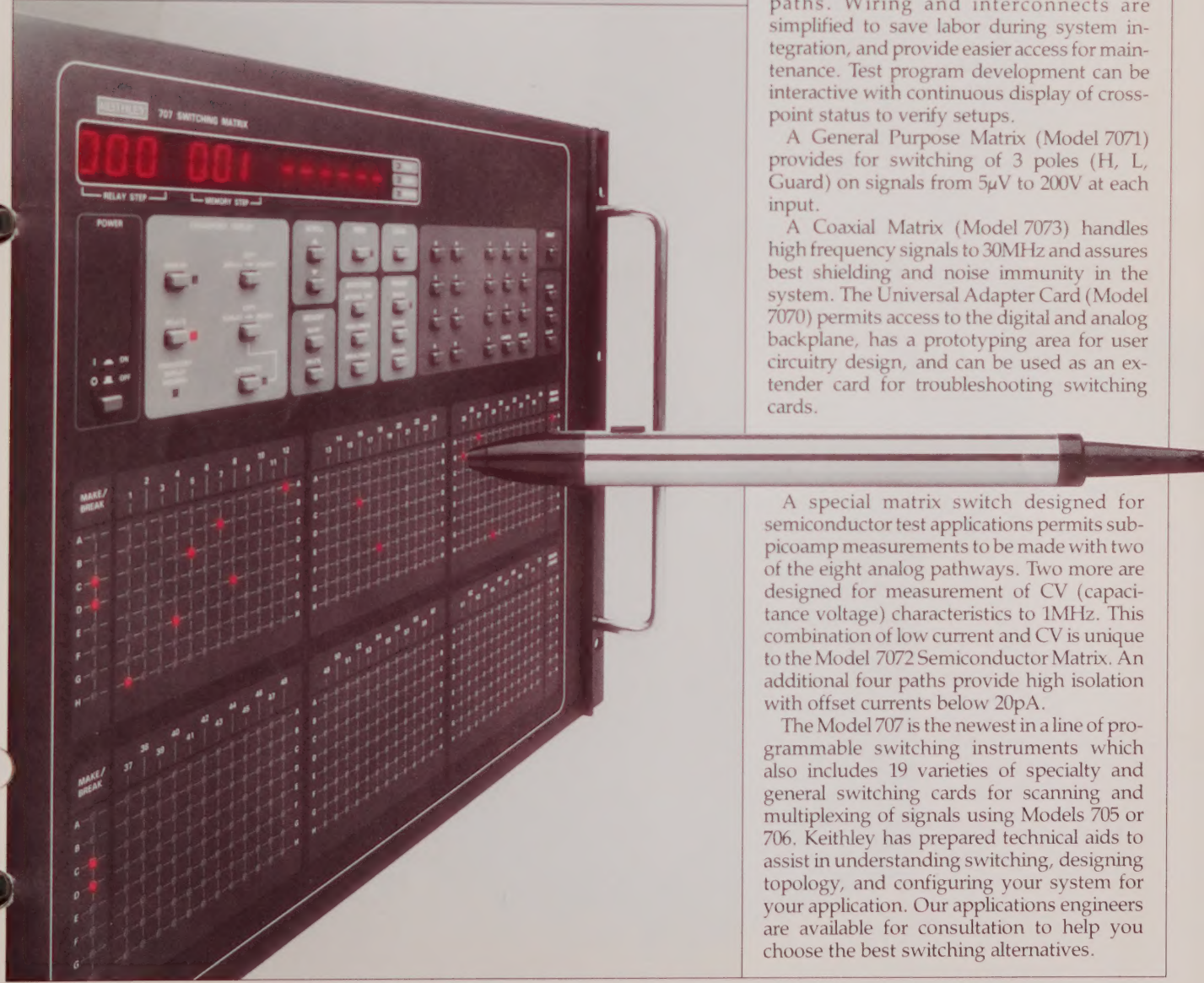




Key Capabilities.

- Variety of 8 x 12 matrix cards to match your signals
- Expand in groups of 12 to 360 columns (2880 matrix crosspoints)
- Saves system integration and test program development time
- Two subpicoamp and two CV pathways for semiconductor application
- 100 setup non-volatile matrix memory

The Model 707 Switching Matrix will save you time and money in designing, integrating, verifying, and maintaining your test system and test software. The matrix configuration provides maximum flexibility in signal switching and makes configuring a system easier, allowing multiple input pins to be connected to any others through simple paths. Wiring and interconnects are simplified to save labor during system integration, and provide easier access for maintenance. Test program development can be interactive with continuous display of crosspoint status to verify setups.

A General Purpose Matrix (Model 7071) provides for switching of 3 poles (H, L, Guard) on signals from 5μV to 200V at each input.

A Coaxial Matrix (Model 7073) handles high frequency signals to 30MHz and assures best shielding and noise immunity in the system. The Universal Adapter Card (Model 7070) permits access to the digital and analog backplane, has a prototyping area for user circuitry design, and can be used as an extender card for troubleshooting switching cards.

A special matrix switch designed for semiconductor test applications permits subpicoamp measurements to be made with two of the eight analog pathways. Two more are designed for measurement of CV (capacitance voltage) characteristics to 1MHz. This combination of low current and CV is unique to the Model 7072 Semiconductor Matrix. An additional four paths provide high isolation with offset currents below 20pA.

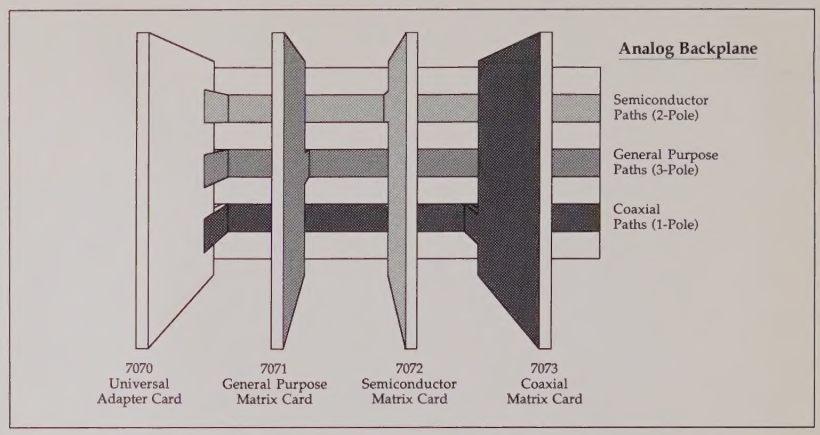
The Model 707 is the newest in a line of programmable switching instruments which also includes 19 varieties of specialty and general switching cards for scanning and multiplexing of signals using Models 705 or 706. Keithley has prepared technical aids to assist in understanding switching, designing topology, and configuring your system for your application. Our applications engineers are available for consultation to help you choose the best switching alternatives.

Goes Together Fast.

Analog Backplanes

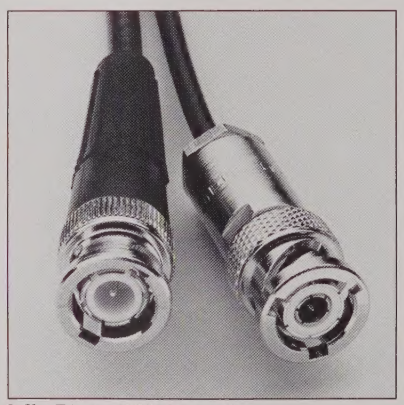
Three separate analog backplanes, each with eight isolated signal paths, automatically make row connections between cards of a given family. Separating the analog backplanes permits designing each to maintain the performance characteristics within a card family when multiple card types are mixed within a mainframe.

Within a mainframe, matrix cards are connected along the rows via the analog backplanes. This reduces the need for complex harnesses and external wiring while saving time in design and system integration.

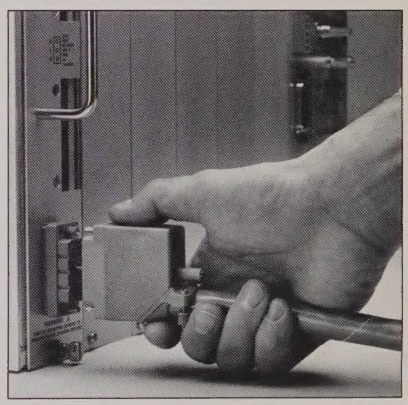


	Backplane		
Card Family	General Purpose	Semiconductor	High Frequency
Model 7070 Universal Adapter	X	X	X
Model 7071 General Purpose	38 Pin Multiple Termination Block		
Model 7072 Semiconductor		Triax	
Model 7073 Coaxial			BNC

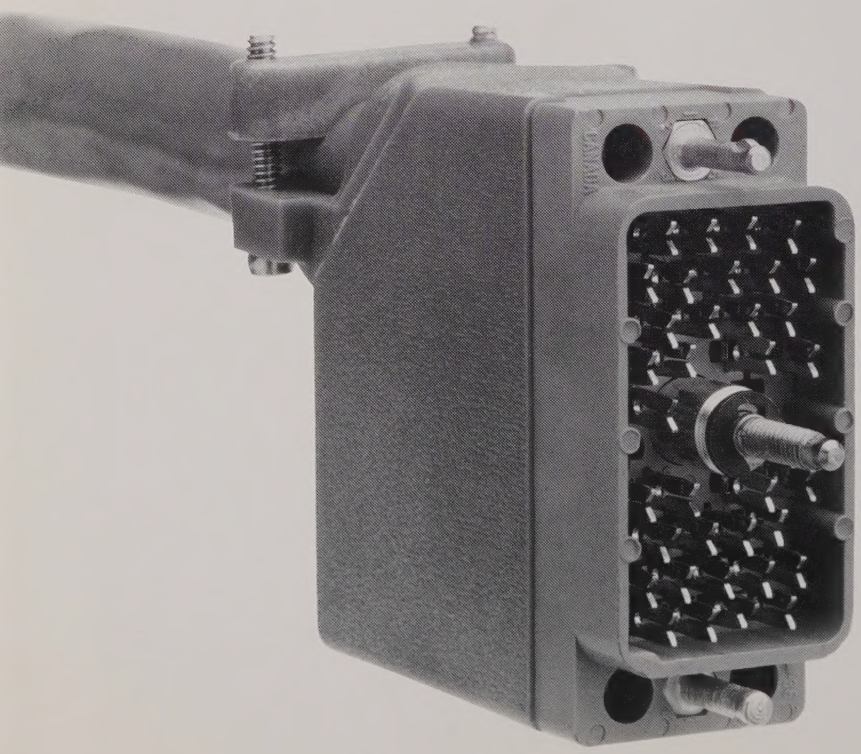
When card families are mixed within a mainframe, each is in fact a separate and isolated matrix configuration operating under one control.



3-Slot Triax and BNC Connections



Multiple pin connector blocks provide fast and easy assembly and disassembly for the 7071 General Purpose Matrix Card.



Quick Connect/Disconnect

Cabling and interconnect to instrumentation and DUT pins are also simplified through the use of standard connector types which can be easily connected and disconnected for system assembly and maintenance. Cable accessories are available in either finished assembly or kit form.

The 7078-MTC Mass Terminated Cable Assembly is preassembled and terminated at both ends with a multiple pin connector block. It contains **12 sets of shielded, twisted pair wires** to minimize noise induced from external system sources. The **20 ft. cable** can be cut in two sections and the unterminated ends routed for custom harnesses and interconnects.

Faster, More Accurate Test Development

Interactive, "One Touch" Programming

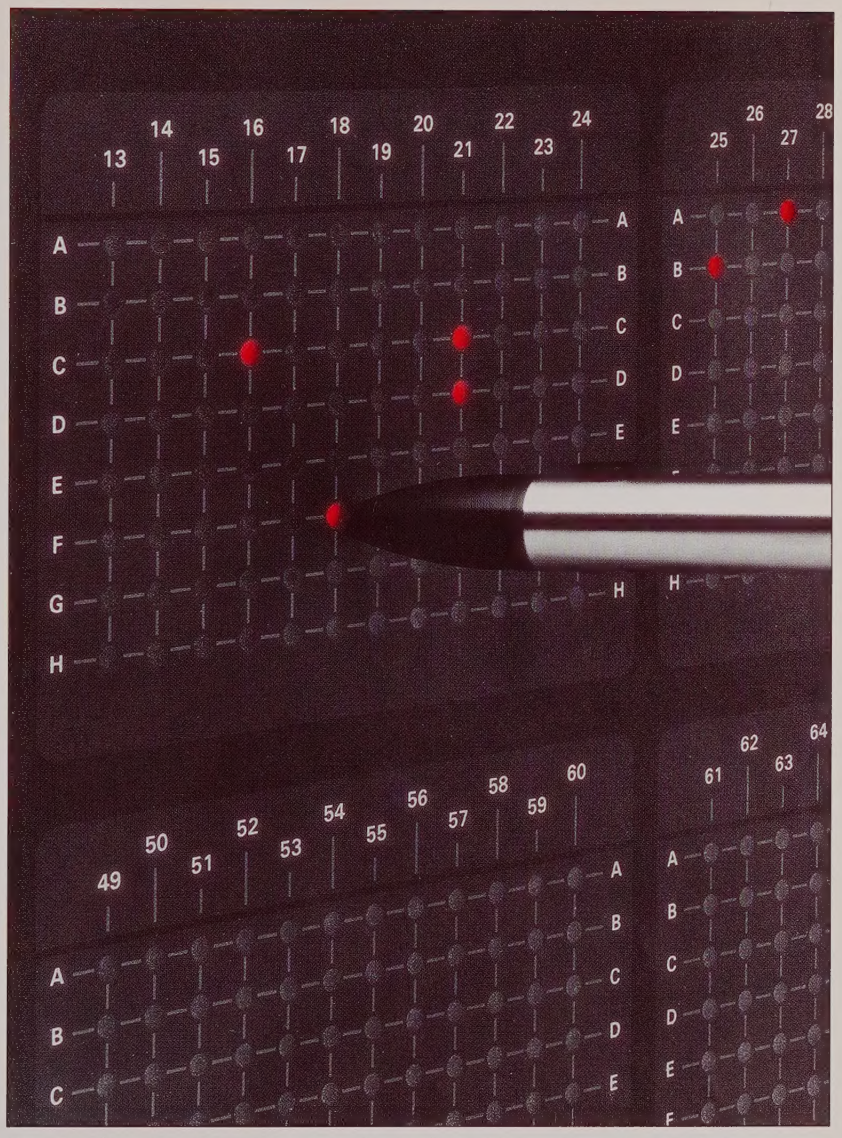
The optional Light Pen operates on the setup memory or directly on the relay states, making test development easy. Simply point the light pen to the display crosspoint and press the button. The front panel provides instant visual feedback of the change for verification and displays continuous status for monitoring setups or debugging tests.

A 100 setup non-volatile memory stores programmed matrix configurations for recall or to upload to a computer file at the end of test development. Stored computer files can be read back into the 707 setup memory to change test sequences or devices.

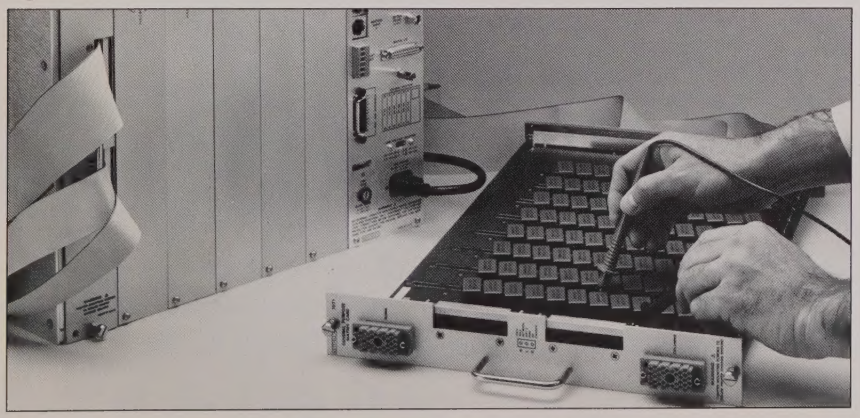
Throughput and System Capability

Matrix setups can be recalled from memory at rates up to 200 setups per second using one of several hardware or software trigger conditions. When a trigger is received, the Model 707 will step sequence to the next location in the internal setup memory. An Output Trigger with programmable delay time is useful for synchronizing with other instruments in the system. Hardware triggers can be programmed for either positive or negative edges.

16 channels of digital input and 16 channels of digital output are provided in the 707 mainframe. Input lines can be used to check logic states on DUTs, verify that safety interlocks are made, or to confirm DUT or test interface ID before proceeding with testing. The instrument can be set to send an SRQ over the IEEE-488 bus whenever any digital input changes state. Digital outputs are useful for controlling system events or external relay states and for providing logic levels to test circuits.



"One Touch" programming saves time during test development. Point the light pen, press the button and the crosspoint changes state. Confirm the setup visually before sending it to the relays or to the non-volatile setup memory.



Switching cards may be removed from the mainframe for locating possible relay faults. The Model 7070 Universal Adapter Card extends the analog and digital backplanes for control and troubleshooting.

Simplified Maintenance

Access for maintenance is made easier by the quick disconnect cable terminations. Once these cables are disconnected a relay card can be removed and a Model 7070 Universal Adapter Card installed in its place. This card extends the relay card and provides access to all of the analog and digital backplanes for troubleshooting.

A connector on the rear panel of the 707 provides test signals to the relay card, and a disk is available for IBM-PC compatibles or HP 9000 series computers to help localize relay faults. This can also be used as a quick confidence check for periodic preventive maintenance on the switching system.

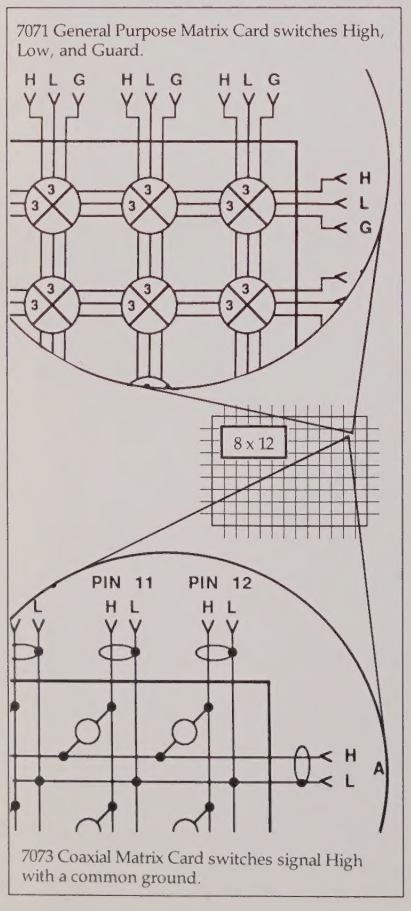
Switching Variety for Applications in Electronics

7071 General Purpose Matrix Card

• 3-Pole High, Low, & Guard Switched

This configuration allows for considerable flexibility when designing your system wiring and interconnect. The switch adapts for single ended or two-wire applications with switched shield. It may also be configured for floating and/or differential measurements. In this case, Guard may be connected to Ground, Low, or Chassis to achieve noise shielding outside of the 707 mainframe.

This card may also be used to switch circuit high and high sense for half of a 4-wire configuration. This is useful for precision applications where compensation such as remote sense in dc sources and 4-wire resistance measurements in digital multimeters is used to achieve signal integrity at the DUT interface. Consult the 707 Configuration Guide and Keithley's Switching Handbook for helpful discussions on switching alternatives and helpful switching design hints.



7071 General Purpose Matrix Card switches High, Low, and Guard.

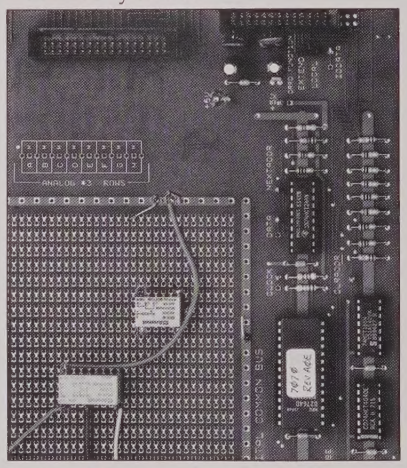
7073 Coaxial Matrix Card switches signal High with a common ground.

• Voltages from 5μV to 200V

Offset voltages created by thermal differences in circuits can overwhelm the dc or resistance accuracy and sensitivity that you need from your high resolution DMM. The Model 7071 General Purpose Matrix Card contributes less than 5μV of offset to any circuit, and it can switch signals to 200V peak.

• Currents to 1A

Current capacity is important when switching power supplies, electronic devices, and certain transducers. The relays on the Model 7071 are rated for current carry of 1A.



96 open collector relay drivers and 117 square inches (7600 cm²) of prototyping area on the Model 7070 Universal Adapter Card allow for custom circuits and switching.

7073 Coaxial Matrix Card

• 30 MHz Bandwidth

The Model 7073 Coaxial Matrix Card is useful for high frequency signals below 30MHz. It provides a 50Ω characteristic impedance and path isolation up to 80dB below 1MHz. Jumpers can be removed to disconnect the matrix card pathways from the analog backplane.

• Shielding Reduces System Noise

External signal wiring, harnesses, and interconnects can be susceptible to induced noise from nearby sources, or can be sources of noise themselves. Using a coaxial matrix and wiring shields the sensitive signal conductors and helps to eliminate noise from the circuit.

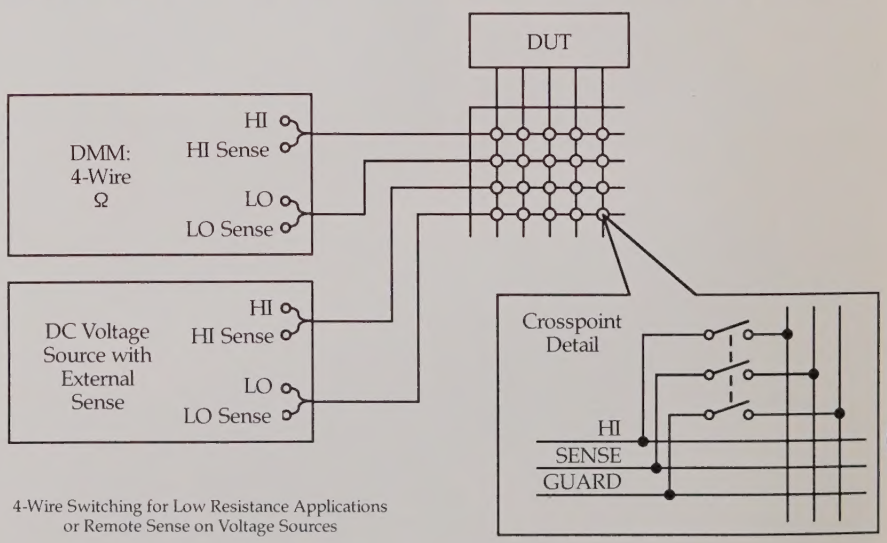
7070 Universal Adapter Card

• Circuit Prototyping

The Model 7070 provides access to all of the analog backplanes as well as to 96 open collector relay drive lines. An area is provided with plated through holes on 0.1" centers on which to mount components and user designed circuits.

• Maintenance Aid

The adapter card can also be used to extend the analog backplane and digital control to matrix cards which have been removed for troubleshooting. This assures easy access for measurements, and the relay test software can help to localize possible defective relays.



4-Wire Switching for Low Resistance Applications or Remote Sense on Voltage Sources

Unique Semiconductor Capabilities

7072 Semiconductor Matrix Card

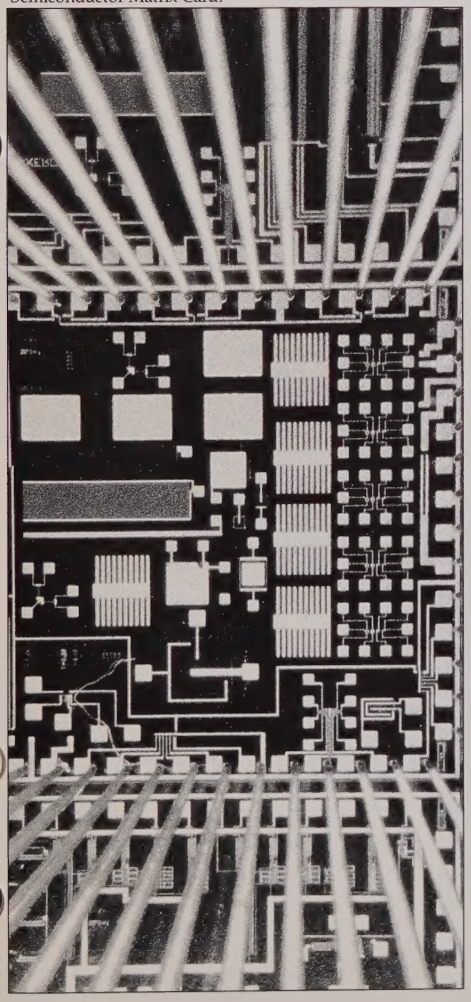
As the core of your semiconductor test system, the Model 707 Switching Matrix with the Model 7072 Semiconductor Matrix Card combines capabilities never before found in one switching mainframe. These include:

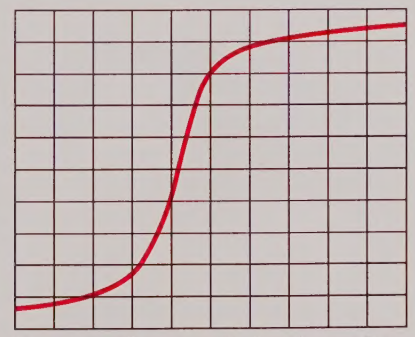
- Two isolated low current signal paths with offset current specified <1pA.
- Two dedicated paths for CV measurements from dc to 1MHz.
- Four general purpose signal paths for currents from <20pA to 100mA and voltages to 200V.

Also included are:

- 3-lug triaxial inputs and fully guarded circuits.
- Expansion in increments of 12 up to 360 pins.
- "One Touch" light pen programming convenience.
- Programmable make-before-break and break-before-make relay switching.

Automate subthreshold IV and gate leakage tests and achieve subpicoamp measurement resolution with the 7072 Semiconductor Matrix Card.





Use the two CV paths of the 7072 Semiconductor Matrix Card to acquire high frequency capacitance voltage characteristics with the 590 CV Analyzer.

Subpicoamp Current Resolution

Two fully guarded low current paths with isolation relays disconnect these critical circuits from others in the matrix to achieve <1pA offset current. Subpicoamp currents can be resolved, which means that now you can automate without degrading subthreshold and other sensitive measurements.

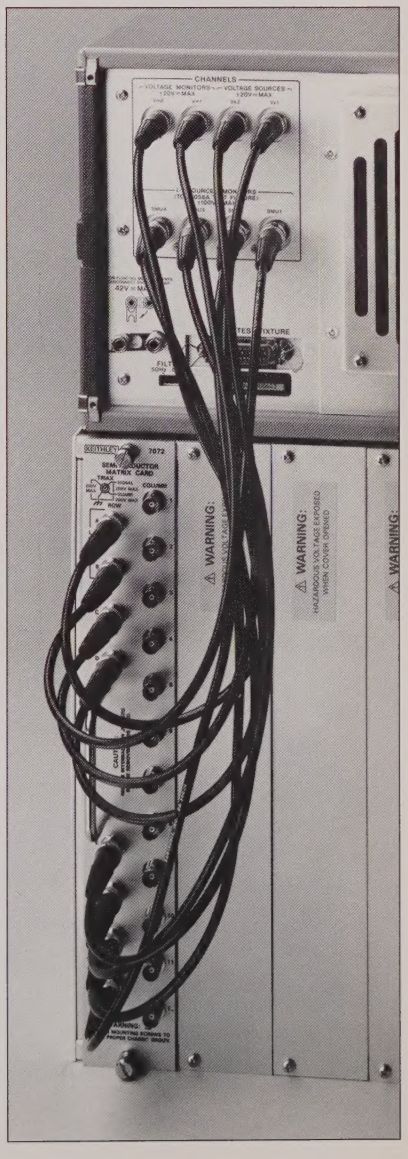
The inputs connectors are 3-lug triax with the outer shell connected to chassis for safety and shielding. The two inner conductors may be used either in a fully guarded configuration or to switch both circuit High and Low.

The Model 7078-CSHP cable set contains all of the cables necessary to connect the HP-4145 Semiconductor Parameter Analyzer to the 7072 Semiconductor Matrix Card. These connections can be routed through any of 8 signal paths to any of up to 72 triaxial inputs within one 707 Switching Matrix.

Capacitance Voltage Measurements

The two CV paths support either quasistatic or high frequency CV measurements to 1MHz, or they can be used for switching low current circuits with a common ground. They are isolated from the other circuits in the matrix by relays to minimize capacitance and dc offset currents.

To achieve the greatest system accuracy and resolution, it is best to use these signal paths with instruments that correct for cable capacitance and dc offset currents. Keithley Models 590 CV Analyzer and 595 Quasistatic CV Meter include compensation algorithms for these errors.



Let Keithley Help with Your Total System.

Semiconductor CV Measurements – Correcting for Cable Capacitance

Uncompensated lead capacitance limits the accuracy and sensitivity that can be achieved in CV measurements. In a switching system the problem is compounded by very large cable capacitances.

The Model 590 CV Analyzer allows for cable correction of a fixed cable length by measuring the value of a known capacitance standard at the end of the cable and storing the correction factor. Up to seven correction factors can be stored.

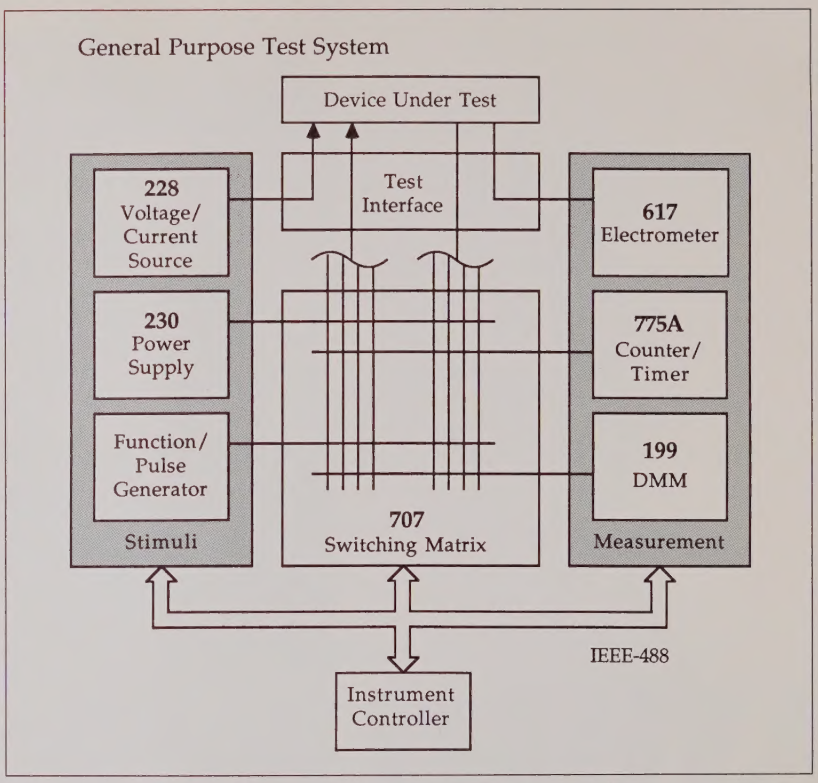
Cable corrections can be controlled through the matrix switch by matching the cable lengths used for external connections, grouping CV measurements on dedicated adjacent pins of the matrix card to control electrical path length, and compensating the circuit using the Model 5907 or 5909 Calibration Capacitors at the proper interface end of the cable. This procedure will compensate for all of the capacitance except that in the last few inches of cable and probe tips. Compensation to the probe tips can be accomplished using known capacitance values on a wafer as transfer standards.

The Model 585 Quasistatic CV Meter uses a unique ''feedback charge'' method for correcting errors due to dc background currents. It speeds testing by providing rapid determination of equilibrium state on the device.

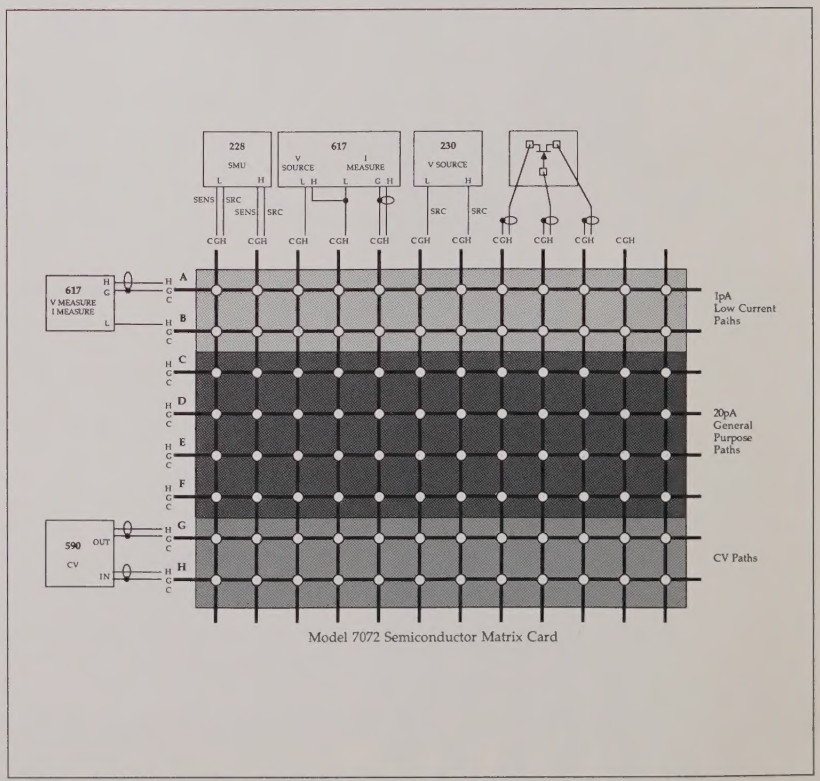
Supplemental Switching

The Model 707 Switching Matrix is part of a family of programmable switching products from Keithley which includes the Models 705 and 706 Scanner mainframes and 19 general purpose and specialty switching cards. These scanner mainframes are well-suited to small systems and to applications which must be optimized for a particular signal type, such as voltages to 1000V, currents to 5A, or frequencies to 500MHz. Thermocouple switching with built-in reference junction, isolated relay switching, and mercury wetted relay switching are also among the variety of switching cards available for the Models 705 and 706.

Many systems do not require the full flexibility of a matrix. Scanning and multiplexing applications are easily configured using one of the two scanner mainframes and any combination of cards.



Matrix switching is the most flexible type of system topology. It allows any set of devices or inputs to be connected together and it is easily expanded to adapt to new test requirements.



Model 7072 Semiconductor Matrix Card

A representative configuration for semiconductor test utilizes both the low current and CV pathways to test an FET device. Additional columns may be added in increments of 12 for interfacing to multipin probe stations.

Large system and 707 matrix configurations may require supplemental switching to handle special signal requirements such as high voltage or currents or to achieve critical system performance at selected DUT pins. The 705 and 706 scanner mainframes and switching cards can be combined with the 707 matrix to satisfy the "special case."

In the U.S., call Keithley's Applications Department or the sales office in your country and talk to one of our engineers about the best solution for you.

Workhorse DMMs

Whether you are looking for economy, speed, or accuracy, check Keithley's complete line of digital multimeters. From the 6½-digit Model 196 to our new Model 199 DMM/Scanner, you will find the measurement performance you need in a quality instrument.

The Model 194A High Resolution Digitizer can both acquire waveforms whose frequency components are below 500kHz and take externally triggered samples at rates as high as 1M samples/second. With the Model 1944A Channel 2 option, two waveforms or two externally-triggered sets of samples can be taken simultaneously.

In addition to waveform acquisition, the Model 194A also provides waveform analysis capability with eight built-in computation functions. The 194A directly computes a waveform's positive and negative peaks, the peak-peak, an average, or an rms value. The rms computation is accurate for any type of waveform.

Ask for your own copy of Keithley's DMM Shortform brochure and learn about the entire line.

Picoamps and Gigaohms

Semiconductor devices, insulating materials, capacitor dielectrics, and other materials share a common property of high dc resistance. The proper way to measure these properties is with an electrometer or with a picoammeter and a source. These high impedance devices and circuits designed with them may also require the input impedance of an electrometer to measure voltage without loading the measurement.

Keithley has the instruments and one of the only switching lines capable of automating the measurement. Learn about low current and high impedance measurements from Keithley's *Low Level Measurements Handbook.*

Source V, Measure I/ Source I, Measure V

This describes the bulk of testing performed on circuits or devices. We are looking for a response to some stimulus.

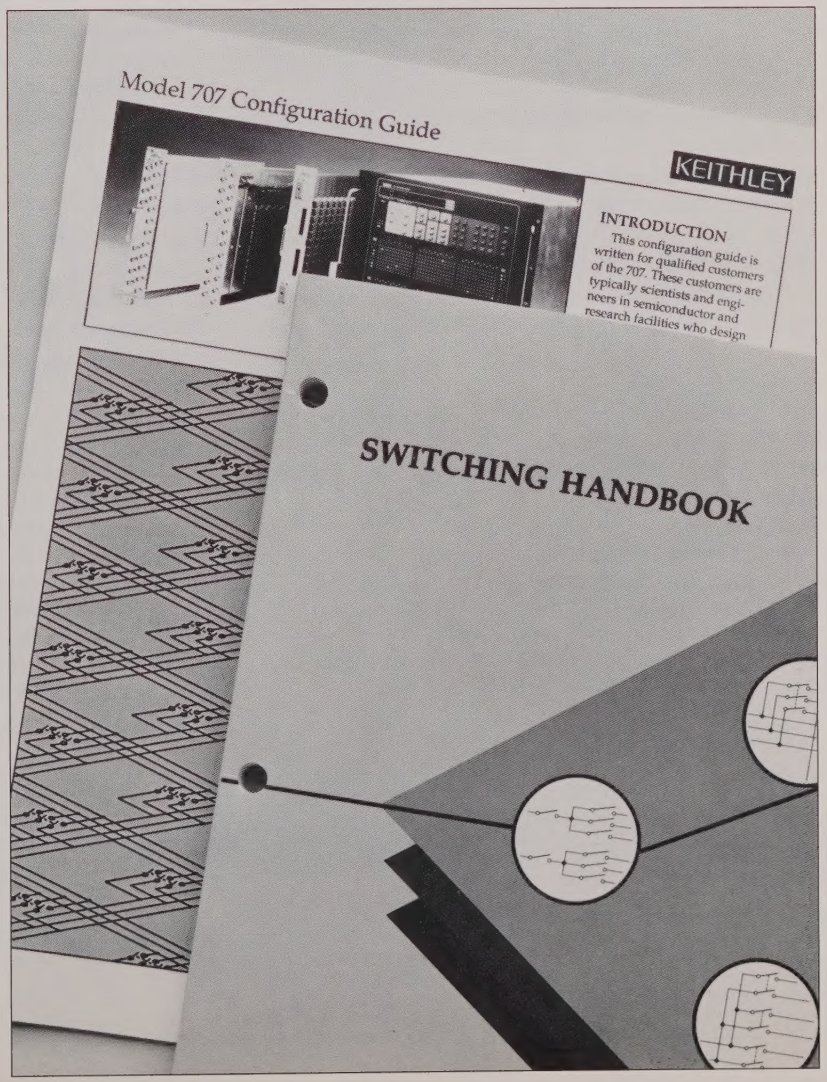
Keithley sources are more than just power supplies; they are dc instruments designed to supply precision voltage or current. Sources deliver performance over and above power supplies in one or more of these characteristics:

- Dynamic range of output
- Sensitivity
- Power source or sink
- Programmability
- Output impedance and isolation
- Transient response

Keithley's line of dc voltage and current sources spans the range of μV to 100V and picoamps to 10A, and are used in combination with electrometers, picoammeters and DMMs to satisfy your Source/Measure/Connect requirements.

and more . . .

Keithley has a complete range of Source, Measure and Connect instrumentation, the measurement knowledge, and the desire to help you get the most out of your system. In the U.S. call the Applications Department at the number below for assistance with your application, information on Keithley products, or to request your personal copy of the 707 Configuration Guide or Switching and Low Level Measurements handbooks. Phone 1-800-552-1115 for assistance in the continental United States. Outside of the U.S. contact your local sales office.


Model 707 Configuration Guide
KEITHLEY
INTRODUCTION
This configuration guide is written for qualified customers of the 707. These customers are typically scientists and engineers in semiconductor and research facilities who design
SWITCHING HANDBOOK

OVERVIEW

CAPACITY: Six plug-in cards per mainframe.

EXPANSION CAPACITY: Daisy-chain expansion of up to four Slave units with one Master unit.

ANALOG BACKPLANES: Backplanes provide automatic row expansion between similar relay cards within one mainframe.

DISPLAY: 14-segment alphanumeric LED display, plus individual status LEDs.

MEMORY: Storage for 100 matrix setups, lithium battery backup.

PROGRAMMED SETTLING TIME: 0 to 65 seconds in 1ms increments.

FRONT PANEL MENU: Digital I/O; External Trigger edge; Matrix Ready level; Master/Slave operation; IEEE-488 address; Relay Settling Time; Self Test; Card Identify; factory defaults.

TRIGGER SOURCES: External Trigger (TTL compatible, programmable edge, 600ns minimum pulse width); IEEE-488 bus (TALK, GET, "X"); manual.

STATUS OUTPUT: Matrix Ready (TTL compatible, programmable high- or low-true): goes false when relays are switched, true at end of Programmed Settling Time.

MAKE BEFORE BREAK, BREAK BEFORE MAKE: Programmable by row.

LIGHT PEN OPTION: Controls crosspoints, memories, make before break and break before make. One light pen controls Master and all Slaves.

EXECUTION SPEED

MAXIMUM TRIGGER RATE: 200 setups per second (stepping through previously stored setups with make-before-break and break-before make disabled).

TRIGGER RESPONSE TIME:

External Trigger: <1ms.
IEEE-488 GET: <1ms.

RESPONSE TO IEEE-488 COMMAND (to close a single relay, excluding relay settling time):

Stand Alone: <15ms.
Master and Four Slaves: <55ms.

DOWNLOAD TIME (one setup to 707):

Stand Alone: 50ms typical.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: All parameters programmable except for IEEE-488 bus address and Master/Slave operating mode.

GENERAL

DIGITAL I/O (TTL compatible):

Data: 8 inputs, 8 outputs.

Control: Input Latch, Output Strobe, Matrix Ready.

REAR PANEL CONNECTORS:

Two BNC: External Trigger, Matrix Ready.
One DB-25: Digital I/O.
Two 8-pin DIN: Master/Slave In, Master/Slave Out.
One 6-pin screw terminal plug: Relay Test.

ENVIRONMENT: **Operating:** 0 to 50°C.
Storage: −25 to 65°C.

POWER: 90-125V ac or 180-250V ac (internally/externally selected), 50-60Hz, 140VA maximum.

RELAY DRIVE: 2.9A minimum.

DIMENSIONS, WEIGHT: 356mm high × 432mm wide × 574mm deep (14 in. × 17 in. × 22.6 in.). Net weight without cards 18.2kg (40 lbs.).

ACCESSORIES SUPPLIED: Instruction manual, power line cord, relay test connector, fixed rack mounting hardware.

ACCESSORIES AVAILABLE:

Model 7070:	Universal Adapter Card
Model 7071:	General Purpose Matrix Card
Model 7072:	Semiconductor Matrix Card
Model 7073:	Coaxial Matrix Card
Model 7078-DIN:	8-Pin DIN Cable (Master/Slave), 1.8m (6 ft.)
Model 7078-PEN:	Programming Light Pen (includes holder)
Model 7079:	Slide Rack Mounting Kit
Model 7007-1:	Shielded IEEE-488 Cable, 1m (3.2 ft.)
Model 7007-2:	Shielded IEEE-488 Cable, 2m (6.6 ft.)
Model 7051-2:	BNC to BNC Cable, 0.6m (2 ft.)
Model 7051-5:	BNC to BNC Cable, 1.5m (5 ft.)

Prices and specifications subject to change without notice.

KEITHLEY

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PACKING SLIP #: NPS
CARRIER: UPS
OF PKGS: 02
PRO #: SAM
RECEIVER PAN: A68217

3-8-89 Pat Koci x395 will put thru the 707 mainframe. Callback in 2 days
3-10-89 Emily say no news yet
3-13-89 - Rx'd MAINFRAME, 3 TRX-B

ITEM NO	QUANTITY ORDERED	MODEL	RECEIVED TODAY	CUMULATIVE RECEIVED TO-DATE	BACKORDER/ OVERSHIP(-)
001	1 EA	707	1 EA	1 EA	0 EA
	DESCRIPTION - MATRIX MAINFRAME				
002	2 EA	7071	2 EA	2 EA	0 EA
	DESCRIPTION - MATRIX CARD				
003	1 EA	7072	1 EA	1 EA	0 EA
	DESCRIPTION - SEMICONDUCTOR MATRIX CARD				
004	1 EA	7073	1 EA	1 EA	0 EA
	DESCRIPTION - COAX MATRIX CARD				
005	1 EA	7078	1 EA	1 EA	0 EA
	DESCRIPTION - LIGHT PEN				
006	1 EA	7078	1 EA	1 EA	0 EA
	DESCRIPTION - TRIAX CABLES				
007	8 EA	7078-TRX-B	8 EA	8 EA	0 EA
	DESCRIPTION - NC ADAPTERS				

IF YOU CONCUR WITH THE ABOVE, PLEASE DISCARD THIS NOTICE.
IF THE INFORMATION IS INCORRECT, PLEASE MAIL THIS TO YOUR ORIGINATING PURCHASING DEPARTMENT.

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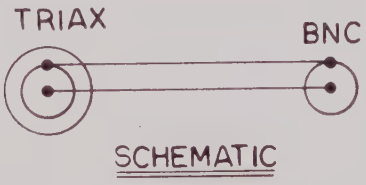
Model 7078-TRX-BNC 3-Lug Triax to BNC Adapter

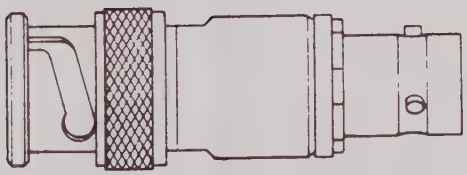
The Model 7078-TRX-BNC is a male 3-slot triax to female BNC adapter. It can be used to connect cables terminated with BNC connectors to equipment having female 3-lug triax connectors (such as the Model 7072 Semiconductor Matrix Card).

NOTE

To maintain maximum insulation resistance, keep the adapter free of contaminants (dirt, oil, etc.). If it becomes contaminated, clean it thoroughly with Freon® or methanol and allow it to dry completely before use.



SCHEMATIC



KEITHLEY

Models 7078-TRX-3 and 7078-TRX-10 3-Lug Triax Cables

The Model 7078-TRX-3 is a 0.9m (3 ft.) triax cable and the Model 7078-TRX-10 is a 3m (10 ft.) triax cable. The cables are terminated at each end with 3-slot triax connectors. They can be used to connect with equipment having female 3-lug triax connectors (such as the Model 7072 Semiconductor Matrix Card).

NOTE

To maintain maximum insulation resistance, keep the cable connectors free of contaminants (dirt, oil, etc.). If they become contaminated, clean thoroughly with Freon® or methanol and allow to dry completely before use.

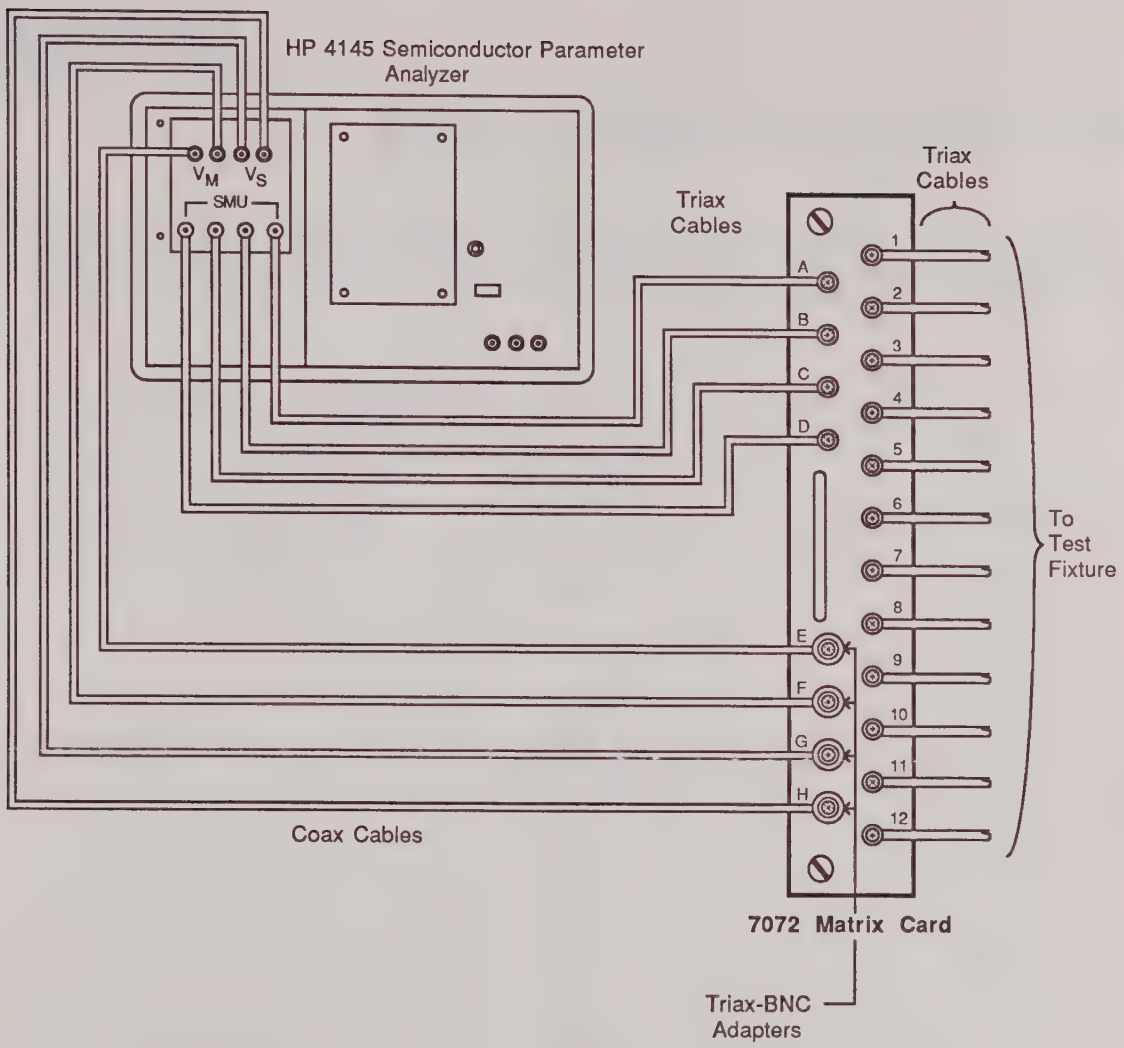


Figure 1. Typical Connections

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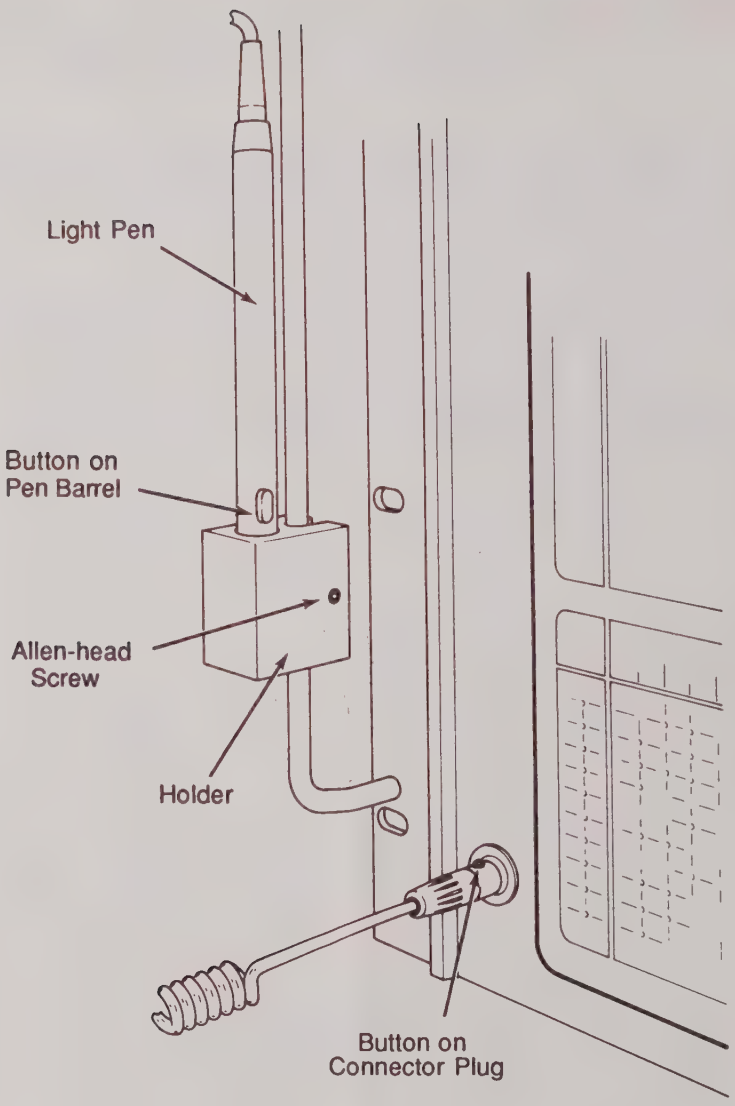
Model 7078-PEN Programming Light Pen

The Model 7078-PEN contains a light pen on a coiled cord and a light pen holder. The light pen is used to toggle the on/off states of crosspoint display LEDs, make/break row LEDs, and break/make row LEDs of a Model 707 Switching Matrix. One light pen, connected to a master unit, controls the LEDs of all units in a master/slave system.

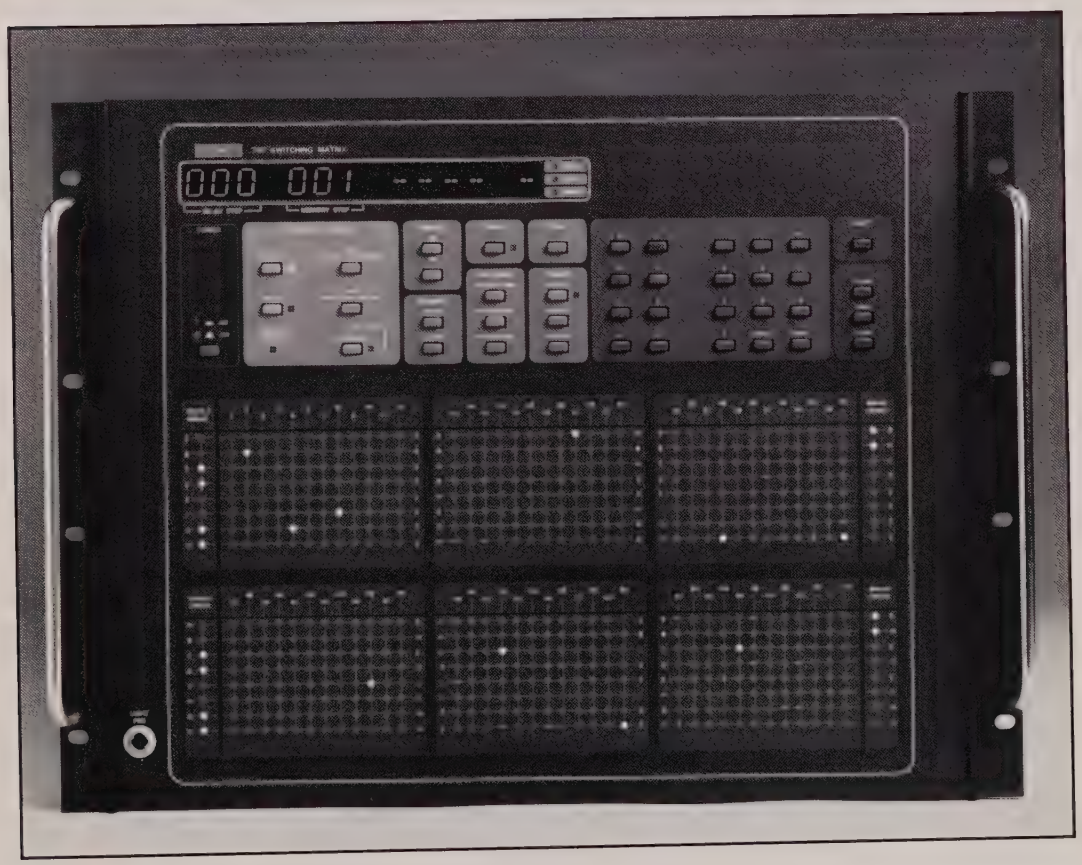
As shown in the figure, the light pen plugs into the front panel (of a stand-alone or master unit). Remove the light pen by pressing the button on the connector plug while pulling out the plug.

The light pen holder is mounted to the left handle of the unit. Secure the holder to the handle by tightening the allen-head screw shown.


Light Pen
Button on
Pen Barrel
Allen-head
Screw
Holder
Button on
Connector Plug

KEITHLEY

Model 707 Switching Matrix Instruction Manual



Contains Operating and Servicing Information

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WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Keithley Instruments, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

KEITHLEY

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Model 707 Addendum

INTRODUCTION

The following information is supplied to provide you with the latest improvements and corrections in the shortest possible time. It is recommended that this information be immediately incorporated into the Model 707 Instruction Manual.

MANUAL CHANGES

The following changes to the Model 707 Instruction Manual are indicated by a vertical bar next to the changed information.

SUPERSEDED
CHGS INCORP
3-13-89

Instruction Manual
Model 707
Switching Matrix

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SAFETY PRECAUTIONS

The following safety precautions should be observed before using the Model 707.

This instrument is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over this manual carefully before operating the instrument.

Exercise extreme caution when a shock hazard is present at the test circuit. User-supplied lethal voltages may be present on the matrix card connector jacks. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS or 42.4V peak are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Inspect the connecting cables and test leads for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the test cables or any instruments while power is applied to the circuit under test. Turn off the power and discharge any capacitors before connecting or disconnecting cables from the matrix cards.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

Do not exceed the maximum allowable input of the matrix cards, as defined in the specifications and operation sections of their manual.

SPECIFICATIONS

OVERVIEW

CAPACITY: Six plug-in cards per mainframe.

EXPANSION CAPACITY: Daisy-chain expansion of up to four Slave units with one Master unit.

ANALOG BACKPLANES: Backplanes provide automatic row expansion between similar relay cards within one mainframe.

DISPLAY: 14-segment alphanumeric LED display, plus individual status LEDs.

MEMORY: Storage for 100 matrix setups, lithium battery backup.

PROGRAMMED SETTLING TIME: 0 to 65 seconds in 1ms increments.

FRONT PANEL MENU: Digital I/O; External Trigger edge; Matrix Ready level; Master/Slave operation; IEEE-488 address; Relay Settling Time; Self Test; Card Identify; factory defaults.

TRIGGER SOURCES: External Trigger (TTL compatible, programmable edge, 600ns minimum pulse width); IEEE-488 bus (TALK, GET, "X"); manual.

STATUS OUTPUT: Matrix Ready (TTL compatible, programmable high- or low-true): goes false when relays are switched, true at end of Programmed Settling Time.

MAKE BEFORE BREAK, BREAK BEFORE MAKE: Programmable by row.

LIGHT PEN OPTION: Controls crosspoints, memories, make before break and break before make. One light pen controls Master and all Slaves.

EXECUTION SPEED

MAXIMUM TRIGGER RATE: 200 setups per second (stepping through previously stored setups with make-before-break and break-before make disabled).

TRIGGER RESPONSE TIME:
External Trigger: <1ms.
IEEE-488 GET: <1ms.

RESPONSE TO IEEE-488 COMMAND (to close a single relay, excluding relay settling time):
Stand Alone: <15ms.
Master and Four Slaves: <55ms.

DOWNLOAD TIME (one setup to 707):
Stand Alone: 60ms typical.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

PROGRAMMABLE PARAMETERS: All parameters programmable except for IEEE-488 bus address and Master/Slave operating mode.

GENERAL

DIGITAL I/O (TTL compatible):
Data: 8 inputs, 8 outputs.
Control: Input Latch, Output Strobe.

REAR PANEL CONNECTORS:
Two BNC: External Trigger, Matrix Ready.
One DB-25: Digital I/O.
Two 8-pin DIN: Master/Slave In, Master/Slave Out.
One 6-pin screw terminal plug: Relay Test.

ENVIRONMENT: **Operating:** 0 to 50°C.
Storage: −25 to 65°C.

POWER: 90-125V ac or 180-250V ac (internally/externally selected), 50-60Hz, 140VA maximum.

RELAY DRIVE: 2.9A minimum.

DIMENSIONS, WEIGHT: 356mm high × 432mm wide × 574mm deep (14 in. × 17 in. × 22.6 in.). Net weight without cards 18.2kg (40 lbs.).

ACCESSORIES SUPPLIED: Instruction manual, power line cord, relay test connector, fixed rack mounting hardware.

ACCESSORIES AVAILABLE:

Model 7070:	Universal Adapter Card
Model 7071:	General Purpose Matrix Card
Model 7072:	Semiconductor Matrix Card
Model 7073:	Coaxial Matrix Card
Model 7078-DIN:	8-Pin DIN Cable (Master/Slave), 1.8m (6 ft.)
Model 7078-PEN:	Programming Light Pen (includes holder)
Model 7079:	Slide Rack Mounting Kit
Model 7007-1:	Shielded IEEE-488 Cable, 1m (3.2 ft.)
Model 7007-2:	Shielded IEEE-488 Cable, 2m (6.6 ft.)
Model 7051-2:	BNC to BNC Cable, 0.6m (2 ft.)
Model 7051-5:	BNC to BNC Cable, 1.5m (5 ft.)

MODEL 707 SWITCHING MATRIX

Specifications subject to change without notice.

Contains information on Model 707 features, specifications, and accessories.

SECTION 1
General Information

Includes an overview of front and rear panel controls, installing matrix cards, card connections, system expansion, and basic switching operation.

SECTION 2
System Start-up

Contains detailed information on operating the Model 707. Use this section as a reference to all front panel operations.

SECTION 3
Operation

Describes information on connecting the Model 707 to the IEEE-488 bus and programming the instrument from a computer.

SECTION 4
IEEE-488 Programming

Includes detailed operating principles and block diagrams for the various circuits within the instrument.

SECTION 5
Principles of Operation

Details maintenance procedures for the Model 707, including fuse replacement, line voltage selection, Relay Test software, and troubleshooting.

SECTION 6
Maintenance

Lists replacement parts, and also includes component layout and schematic drawings for the Model 707.

SECTION 7
Replaceable Parts

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SECTION 1
General Information

1.1 INTRODUCTION

This section contains general information about the Model 707 Switching Matrix. The Model 707 is designed as a programmable switch for connecting signal paths in a matrix topology. It is for applications requiring a large-scale matrix (up to 360 crosspoints per mainframe and 2880 crosspoints per master/slave configuration). Plug-in cards are available for general and special purpose switching applications.

Section 1 is arranged as follows:

1.2 Features
1.3 Warranty Information
1.4 Manual Addenda
1.5 Safety Symbols and Terms
1.6 Specifications
1.7 Unpacking and Inspection
1.8 Repacking for Shipment
1.9 Optional Accessories

1.2 FEATURES

Key features of the Model 707 Switching Matrix include:

- The six-slot mainframe accepts any mix of 8-row by 12-column matrix cards.
- Rows are extended within the mainframe to minimize system wiring and interconnect requirements.
- Storage of 100 sets of relay setups, which can be uploaded or downloaded through the IEEE-488 interface.
- An active front panel LED display shows the current relay status, a stored setup, or an editing scratchpad.
- High-speed triggering of stored setups.
- Make/break and break/make switching are programmable by rows. Operation is transparent to the user and independent of the relay setup.
- With five units connected in a master/slave configuration, the maximum matrix size is eight rows by 360 columns (2880 crosspoints on one IEEE-488 address).
- An optional light pen is available for interactive controlling of relay states, editing stored relay setups, and selecting make/break and break/make rows.

1.3 WARRANTY INFORMATION

Warranty information is located on the inside front cover of this instruction manual. Should your Model 707 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the mainframe for repair, be sure to fill out and include the service form at the back of this manual to provide the repair facility with the necessary information.

1.4 MANUAL ADDENDA

Any improvements or changes concerning the mainframe or manual will be explained in an addendum included with the unit. Be sure to note these changes and incorporate them into the manual before using or servicing the unit.

1.5 SAFETY SYMBOLS AND TERMS

The following symbols and terms may be found on an instrument or used in this manual:

The ⚠ symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The ⚡ symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that could result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage might invalidate the warranty.

1.6 SPECIFICATIONS

Model 707 specifications can be found at the front of this manual. These specifications are exclusive of the matrix card specifications, which are located in their appropriate instruction manual.

1.7 UNPACKING AND INSPECTION

1.7.1 Inspection for Damage

Upon receiving the Model 707, carefully unpack it from its shipping carton and inspect the unit for any obvious signs of physical damage. Report any damage to the shipping agent immediately. Save the original packing carton for possible future reshipment.

1.7.2 Shipment Contents

The following items are included with every Model 707 order:

- Model 707 Switching Matrix
- Model 707 Instruction Manual
- Power line cord
- Relay test connector
- Relay Test Software diskettes
- Fixed rack mounting hardware
- Additional accessories as ordered

1.7.3 Instruction Manual

The Model 707 Instruction Manual is drilled to fit in the supplied three-ring binder. Add any matrix card instruction manuals after the mainframe manual.

If an additional Model 707 Instruction Manual is needed, order the manual package (Keithley Part Number 707-901-00). The manual package includes an instruction manual and any applicable addenda.

1.7.4 Relay Test Software

The Relay Test Software verifies the operation of matrix relay cards designed for use in the Model 707 (e.g., Models 7071, 7072, and 7073). The software is supplied in two media formats:

- 5¼" diskette (Keithley P/N 707-851)—For an IBM PC or compatible with a CEC IEEE-488 interface. (PC-488-CEC is available from Keithley Instruments.)
- 3½" diskette (Keithley P/N 707-852)—For Hewlett Packard Series 200/300 controllers running HP BASIC 4.0.

1.8 REPACKING FOR SHIPMENT

Should it become necessary to return the Model 707 for repair, carefully pack the unit in its original packing carton or the equivalent, and include the following information:

- Advise as to the warranty status of the mainframe.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.9 OPTIONAL ACCESSORIES

The following accessories are available for the Model 707:

Model 7070 Universal Adapter Card—The Model 7070 card installs in the Model 707 and is jumper-selectable for use either as a backplane extender or a breadboard. It has quick disconnect screw terminals and 10-ft. ribbon cables.

Model 7071 General Purpose Matrix Card—The Model 7071 card has 8 rows by 12 columns of 3-pole Form A switching for general purpose applications. It installs in the Model 707 and has mass terminated connectors in addition to quick-disconnect screw terminals.

Model 7072 Semiconductor Matrix Card—The Model 7072 card has 2 rows by 12 columns of 2-pole Form A for low current switching, 4 rows by 12 columns of 2-pole Form A for general purpose switching, and 2 rows by 12 columns of 1-pole Form A for C-V switching. It installs in the Model 707 and has 3-lug triaxial connectors.

Model 7073 Coaxial Matrix Card—The Model 7073 card has 8 rows by 12 columns of 1-pole Form A switching (up to 30MHz) for applications with single-ended instruments. It installs in the Model 707 and has BNC connectors.

Model 7078-DIN 8-pin DIN Cable—The Model 7078-DIN cable has two 8-pin circular (DIN) connectors and is 1.8m (6 ft.) long. Multiple cables are used for connecting Model 707 units in a master/slave configuration through the rear panel master/slave connectors.

Model 7078-PEN Programming Light Pen—The Model 7078-PEN connects to the Model 707 front panel. It is used to toggle the states of crosspoint LEDs, make/break LEDs, and break/make LEDs. A pen holder is included.

Model 7079 Slide Rack Mounting Kit—The Model 7079 kit consists of two sets of support brackets, equipment slides, and hardware for mounting the Model 707 in a standard 19-inch equipment rack or cabinet.

Model 7007 Shielded IEEE-488 Cables—The Model 7007 connects the Model 707 to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter (3.3 ft.) long and has an EMI shielded IEEE-488 connector at each end. The Model 7007-2 cable is identical to the Model 7007-1, but is 2m (6.6 ft.) long.

Model 7051 BNC to BNC Cables—The Model 7051 cables are for making connections to External Trigger and Matrix Ready on the Model 707 rear panel. The Model 7051-2 is a 50Ω BNC to BNC cable (RG-58C), which is 0.6m (2 ft.) long. The Model 7051-5 cable is identical to the Model 7051-2, but is 1.5m (5 ft.) long.

Model 8000-14 Enclosures—The Model 8000-14 is a 19"-wide by 14"-high open-backed steel enclosure. It is supplied with hardware to mount a bench-top Model 707. The top cover of the enclosure can be removed to access jumpers between cards installed in a Model 707.

Model 7073 Coaxial Matrix Card—The Model 7073 card has 8 rows by 12 columns of 1-pole Form A switching (up to 30MHz) for applications with single-ended instruments. It installs in the Model 707 and has BNC connectors.

Model 7078-DIN 8-pin DIN Cable—The Model 7078-DIN cable has two 8-pin circular (DIN) connectors and is 1.8m (6 ft.) long. Multiple cables are used for connecting Model 707 units in a master/slave configuration through the rear panel master/slave connectors.

Model 7078-PEN Programming Light Pen—The Model 7078-PEN connects to the Model 707 front panel. It is used to toggle the states of crosspoint LEDs, make/break LEDs, and break/make LEDs. A pen holder is included.

Model 7079 Slide Rack Mounting Kit—The Model 7079 kit consists of two sets of support brackets, equipment slides, and hardware for mounting the Model 707 in a standard 19-inch equipment rack or cabinet.

Model 7007 Shielded IEEE-488 Cables—The Model 7007 connects the Model 707 to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter (3.3 ft.) long and has an EMI shielded IEEE-488 connector at each end. The Model 7007-2 cable is identical to the Model 7007-1, but is 2m (6.6 ft.) long.

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SECTION 2
System Start-up

2.1 INTRODUCTION

This section contains introductory information on operating your instrument and is intended to help you get your Model 707 up and running as quickly as possible. It includes a brief description of operating controls and connections. Once you are familiar with the material presented here, refer to Section 3 for more detailed information.

Section 2 is organized as follows:

2.2 **Front Panel Familiarization:** Briefly describes each front panel control and outlines display operations.

2.3 **Rear Panel Familiarization:** Outlines each aspect of the Model 707 rear panel, including connectors.

2.4 **Installing and Removing Cards:** Itemizes a general procedure for installation and removal of matrix cards in the Model 707 mainframe.

2.5 **Card Connectors:** Describes where to connect instruments and DUTs to the matrix rows and columns.

2.6 **Expanding Matrix Size:** Discusses methods for expanding the matrix, both internal to the mainframe and with multiple units.

2.7 **Basic Switching Operation:** Provides a general procedure for powering up the Model 707, choosing make/break or break/make operation, modifying the crosspoint display, storing the setup, and sending the setup to the relays.

2.2 FRONT PANEL FAMILIARIZATION

An overview of the Model 707 operation is given in the following paragraphs. The front panel of the instrument is shown in Figure 2-1. Figure 2-2 illustrates setup data transfers within the Model 707. This pictorial will be helpful in understanding the operations of individual front panel keys.

All front panel keys except POWER are momentary contact switches. Some keys have an LED to indicate the selected function. The keys are color-coded into functional groups for ease of operation.

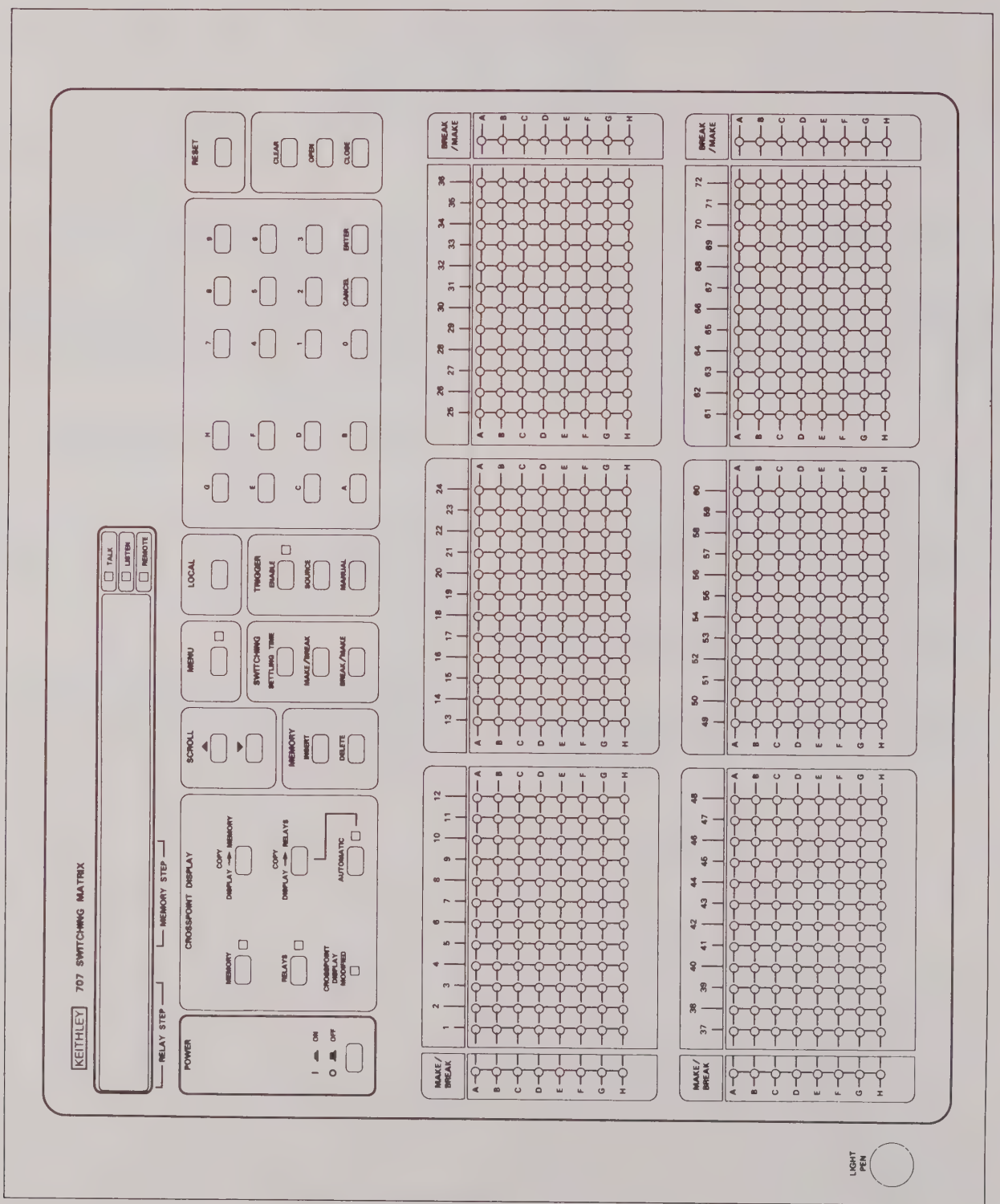


Figure 2-1. Model 707 Front Panel

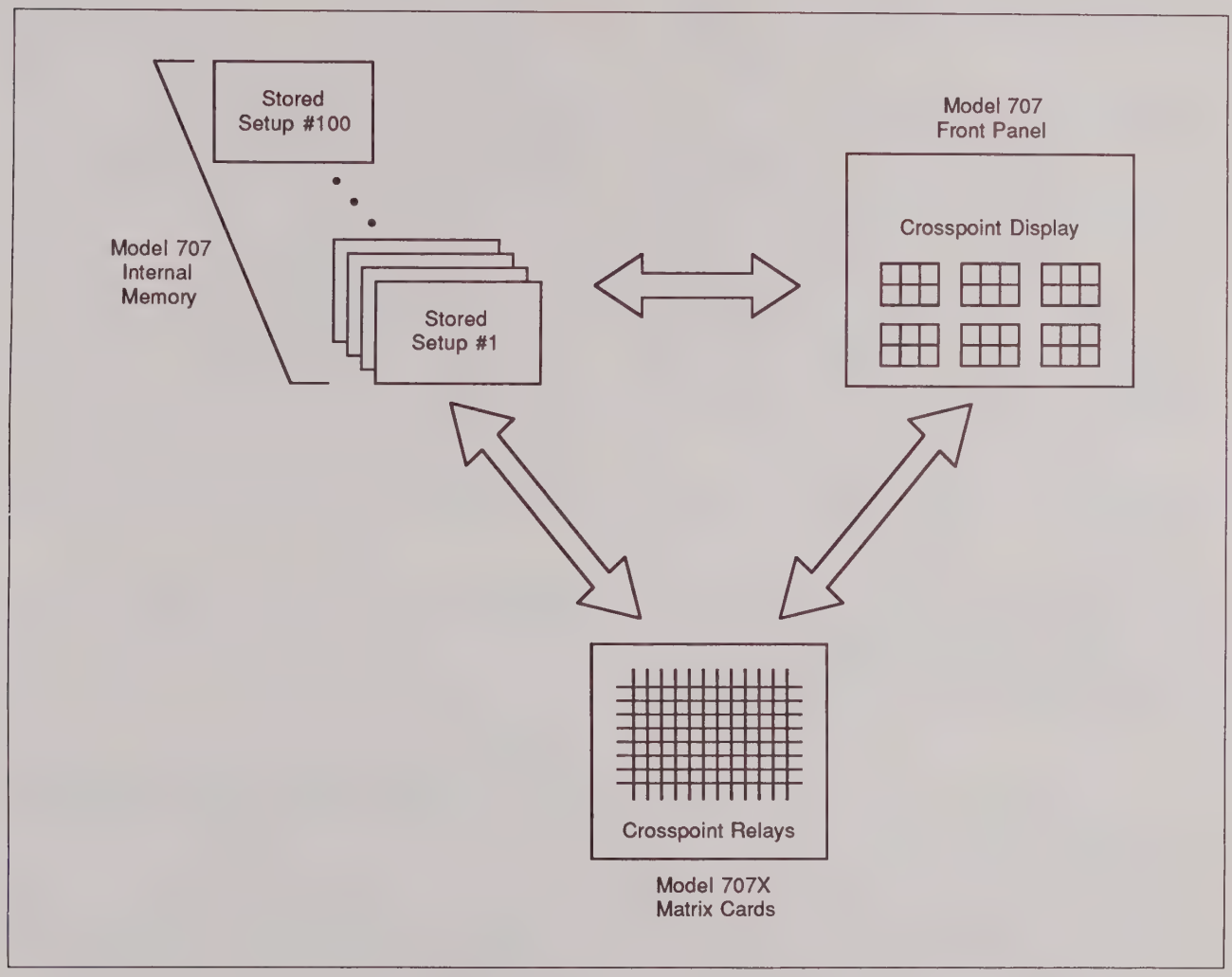


Figure 2-2. Setup Data Transfers

POWER—AC power switch turns the unit on or off.

CROSSPOINT DISPLAY GROUP

MEMORY—Displays a stored relay setup (from location shown in MEMORY STEP field) on the crosspoint display and lights the MEMORY indicator.

RELAYS—Displays the current relay setup on the crosspoint display and lights the RELAYS indicator.

CROSSPOINT DISPLAY MODIFIED—Lights when changes are made to the crosspoint display (by front panel keys or light pen), making it different from the original configuration.

COPY DISPLAY→MEMORY—Copies the displayed crosspoint configuration to the location shown in the MEMORY STEP field.

COPY DISPLAY→RELAYS—Copies the displayed crosspoint configuration to the relays.

AUTOMATIC (COPY DISPLAY→RELAYS)—When this LED is lit, any change to the crosspoint display is sent to the relays at the same time. The pushbutton toggles the LED on an off.

SCROLL GROUP

SCROLL ▲—If MEMORY indicator is lit, increments MEMORY STEP field and displays setup on crosspoint LEDs. If RELAYS indicator is lit, increments RELAY STEP field, displays setup on crosspoint LEDs, and sends setup to relays. Also used for scrolling up through a list of multiple choice parameters.

SCROLL ▼—Same actions as the SCROLL ▲ key except that it decrements and scrolls down.

MEMORY GROUP

INSERT—Inserts a blank setup at the location shown in the MEMORY STEP field. Moves higher stored setups up one memory location.

DELETE—Deletes the setup at the location shown in the MEMORY STEP field. Moves higher stored setups down one memory location.

MENU—Steps through the available menu items:

- View digital input, program digital output.
- Select whether rising or falling edge of External Trigger pulse triggers Model 707.
- Select active high or active low Matrix Ready output signal.
- Select master/slave or stand-alone operation.
- Program IEEE-488 address.
- View longest relay settling time of present card configuration.
- View unit configuration by slot number and card model number.
- Execute self-test.
- Restore factory defaults (and clear stored setups).

Programmable parameters can be changed with the SCROLL or data entry keys and then pressing ENTER.

SWITCHING GROUP

SETTLING TIME—Displays the current value of programmed settling time. (This delay begins after the relay settling time.) To change the value, enter between 0-65000msec and press ENTER.

MAKE/BREAK—Selects rows to operate as make/break (make-before-break) for all setups. First enter row designation (A-H), then press MAKE/BREAK to toggle the state for that row and immediately reprogram the Model 707 for the new operation.

BREAK/MAKE—Same action as MAKE/BREAK except that it selects break/make (break-before-make) rows. (Selecting a row for break/make de-selects it for make/break and vice versa.)

LOCAL—When in remote (REMOTE on), returns the Model 707 to local mode (REMOTE off). It restores operation of other front panel controls unless LLO (Local Lockout) is in effect.

TRIGGER GROUP

ENABLE—Toggles between triggers enabled and triggers disabled. When triggers are enabled, the LED is lit.

SOURCE—Displays current trigger source. Use SCROLL keys to display sources, then press ENTER to select the desired source:

TRIG ON TALK - IEEE talk command
TRIG ON GET - IEEE GET command
TRIG ON X - IEEE X command
TRIG ON EXT - External trigger pulse (rear panel input)
TRIG ON KEY - Front panel MANUAL key only

MANUAL—Generates a trigger from front panel if triggers are enabled (no matter which trigger source is selected). If the trigger source is TRIG ON KEY, only the MANUAL key generates a trigger.

DATA ENTRY (A-H, 0-9)—These keys are for entering row/column addresses and setup locations, selecting make/break and break/make rows, and entering various numeric values.

CANCEL—If the value in the alphanumeric display has been modified, this key restores the current parameter value. If the value in the alphanumeric display has not been modified, this key returns the Model 707 to the previous display. CANCEL also exits from menu mode if no changes have been made.

ENTER—If the value in the alphanumeric display has been modified, pressing this key stores the parameter value. Also invokes immediate action items from the menu and exits menu mode (except when digital I/O is displayed).

RESET—Performs the same functions as cycling power (all relays are opened, triggers are disabled, RELAY STEP to 000, MEMORY STEP to 001, etc.), except powerup self-checking and master/slave loop initialization.

CLEAR—Turns off all crosspoint display LEDs. If the AUTOMATIC (COPY DISPLAY→RELAYS) indicator is lit, all relays are opened immediately.

OPEN—Turns off crosspoint LED of row/column shown on alphanumeric display. If the AUTOMATIC (COPY DISPLAY→RELAYS) indicator is lit, the corresponding relay opens immediately.

CLOSE—Same action as OPEN key except that it turns on the crosspoint LED and relay.

ALPHANUMERIC DISPLAY—A 14-character display that can show:

- Error messages.
- Menu item selections.
- Last setup sent from memory to the relays (RELAY STEP field).
- Last setup recalled from memory to the crosspoint display (MEMORY STEP field).
- Trigger source.
- Programmed settling time.
- Alphanumeric key presses (row/column addresses, setup locations).

IEEE-488 STATUS INDICATORS

TALK, LISTEN, REMOTE—These three LED indicators apply to instrument operation over the IEEE-488 bus. The TALK and LISTEN indicators show when the unit has been addressed to talk or listen. REMOTE turns on to show when the unit is in the IEEE-488 remote state. See Section 4 for detailed information on operation over the bus.

CROSSPOINT DISPLAY LEDs—Show open and closed crosspoints of the current relay setup, a stored relay setup, or an edited relay setup. Each LED block of 8 rows by 12 columns shows on/off states of one card. States can be changed by front panel keys, triggers, or optional light pen. Crosspoint configurations can be stored in memory or sent to relays.

MAKE/BREAK ROW LEDs—Shows which rows are selected for make/break operation. The LEDs can be turned on or off by the MAKE/BREAK, BREAK/MAKE keys or an optional light pen.

BREAK/MAKE ROW LEDs—Same function as MAKE/BREAK row LEDs except for showing which rows are selected for break/make operation. Note that selecting a row for break/make de-selects it for make/break and vice versa.

LIGHT PEN—An optional input device for toggling the on/off state of the Crosspoint Display LEDs, MAKE/BREAK row LEDs, and BREAK/MAKE row LEDs. One light pen is used to control the LEDs of up to five Model 707 mainframes.

2.3 REAR PANEL FAMILIARIZATION

An overview of the rear panel of the Model 707 is in the paragraphs that follow. The rear panel is shown in Figure 2-3. In addition to the various connectors, a column locator diagram for a master or stand-alone unit is provided on the rear panel.

CARD SLOTS—The Model 707 accepts up to six plug-in matrix cards (8 rows by 12 columns) per mainframe.

MASTER/SLAVE OUT—An 8-pin DIN connector for connecting a cable to the next mainframe in a master/slave daisy chain configuration.

MASTER/SLAVE IN —An 8-pin DIN connector for connecting a cable from the previous mainframe in a master/slave daisy chain configuration.

EXTERNAL TRIGGER INPUT—A BNC jack for applying a trigger pulse to change to the next relay setup, if triggers are enabled and TRIG ON EXT is selected as the source. Pulses must be TTL-compatible, negative- or positive-going (selected by a menu item), with a duration greater than 600nsec.

MATRIX READY OUTPUT—A BNC jack providing a TTL-compatible, high- or low-true level (selected by a menu item). It goes false when relays are switched and goes true after the sum of the relay settling time and the programmed settling time.

RELAY TEST—A 6-pin quick-disconnect terminal block with logic ground and four logic inputs for testing cross-point relay closures. Wiring between this terminal block and rows A and B of any card in the group of cards to be tested is necessary for the test.

DIGITAL I/O—A DB-25 connector for the TTL-compatible digital I/O with data lines for eight inputs and eight outputs. It also contains control lines for handshaking (Input Latch and Output Strobe). Input lines are viewed and output lines are programmed through a menu item.

IEEE-488 INTERFACE—This connector interfaces the Model 707 to the IEEE-488 bus. IEEE interface function codes are marked adjacent to the connector.

LINE VOLTAGE SELECTED—The position of this switch determines the operating voltage range of the instrument: 90-110V, 105-125V, or 180-220V, 210-250V.

AC RECEPTACLE—Power is applied through the supplied power cord to the 3-terminal AC receptacle.

LINE FUSE—The line fuse provides protection for the AC power line input. The fuse rating must match the line voltage setting.

FAN FILTER—The fan filter keeps dirt from being drawn into the instrument by the internal cooling fan. The filter should be kept clean to ensure proper instrument cooling.

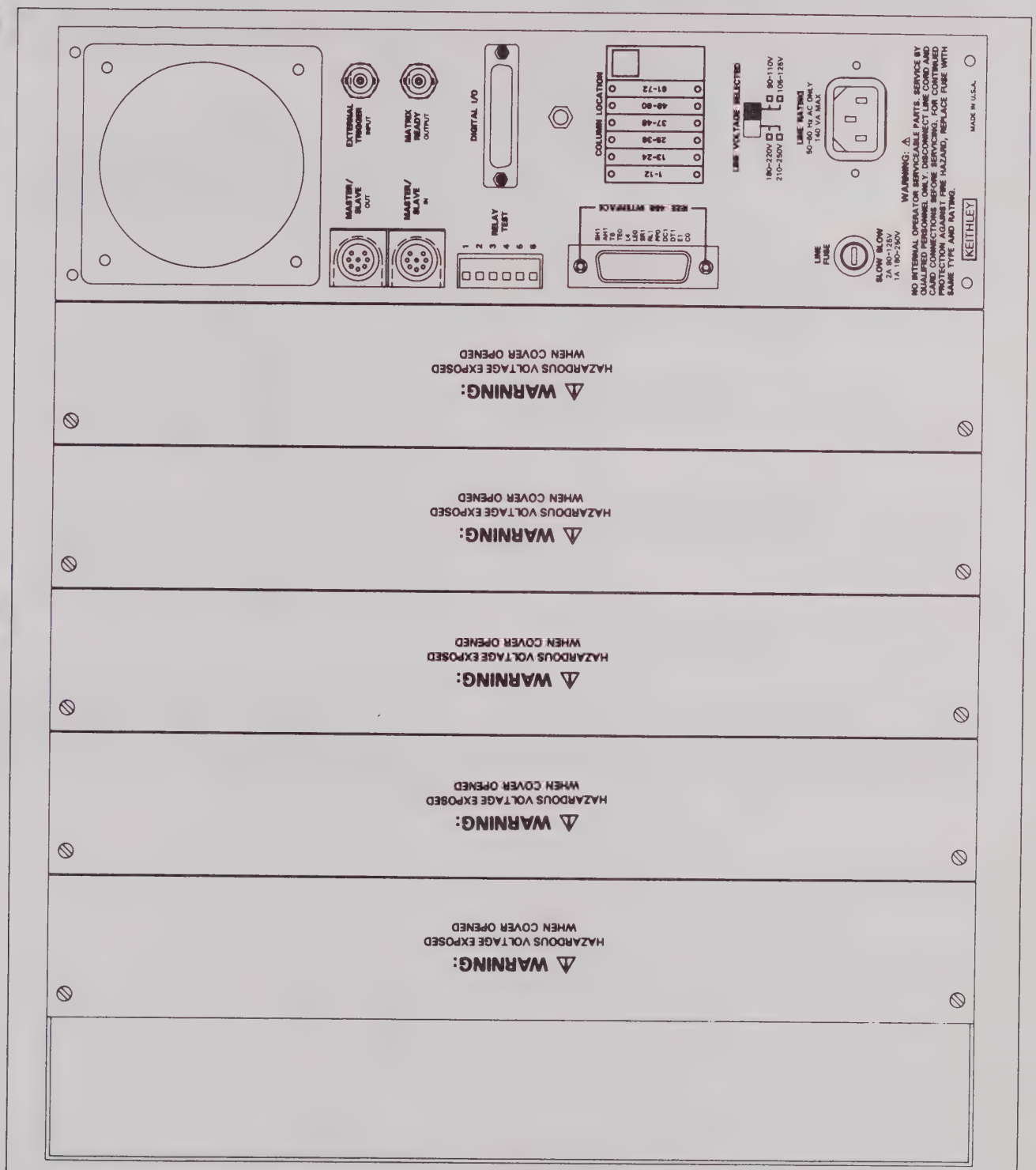


Figure 2-3. Model 707 Rear Panel

2.4 INSTALLING AND REMOVING CARDS

Before operating the Model 707 in a test environment, matrix cards (up to six per mainframe) must be installed into the mainframe. Note that matrix cards are not necessary to program setups. Setups for master/slave configurations can be programmed as long as the MASTER/SLAVE OUT to MASTER/SLAVE IN loop connections are present. (See paragraph 2.6.2.)

WARNING

Before installing/removing cards or making card connections, turn off mainframe power and disconnect the line cord. Also, ensure that no power is applied from the user's circuit.

Install a card in the Model 707 as follows, using Figure 2-4 as a guide. Instructions specific to each card can be found in the appropriate card manual.

CAUTION

Do not touch the card surfaces, connectors, or components to avoid contamination that could degrade card performance.

1. Ensure that the access door on top of the mainframe is fully closed and locked down. (The bottom side of the access door has card guides.)
2. Remove the slot cover from the desired slot.
3. With one hand grasping the card's handle, and the other supporting its weight, line up the card with the card guides in the slot. Ensure that the component side is facing the fan of the mainframe.
4. Slide the card into the mainframe until it is fully seated in the backplane connectors. Finger-tighten the spring-loaded mounting screws at the back of the card to lock it in place.

WARNING

The mounting screws must be secured to ensure a proper chassis ground connection between the card and the mainframe. Failure to properly secure this ground connection may result in personal injury or death due to electric shock.

NOTE

Some cards have connectors that are inaccessible once the card is fully inserted into the mainframe (e.g., the quick disconnect terminal blocks on Model 7071 cards). In these cases, connect wires to the row and column terminal blocks before seating it in the backplane connectors.

The SMB coax jumpers used between Model 7072 cards do not have to be installed before the cards are inserted. Use the access door on top of the mainframe for this purpose. (Because of the access door, the Model 7079 slide rack kit is recommended for rack-mounted units.)

5. To remove a matrix card, first turn off the mainframe and disconnect the line cord. Ensure no voltage is applied from the user's circuit. Remove any internal cabling between cards through the unit's access door. Loosen the spring-loaded mounting screws and pull out the card by its handle.

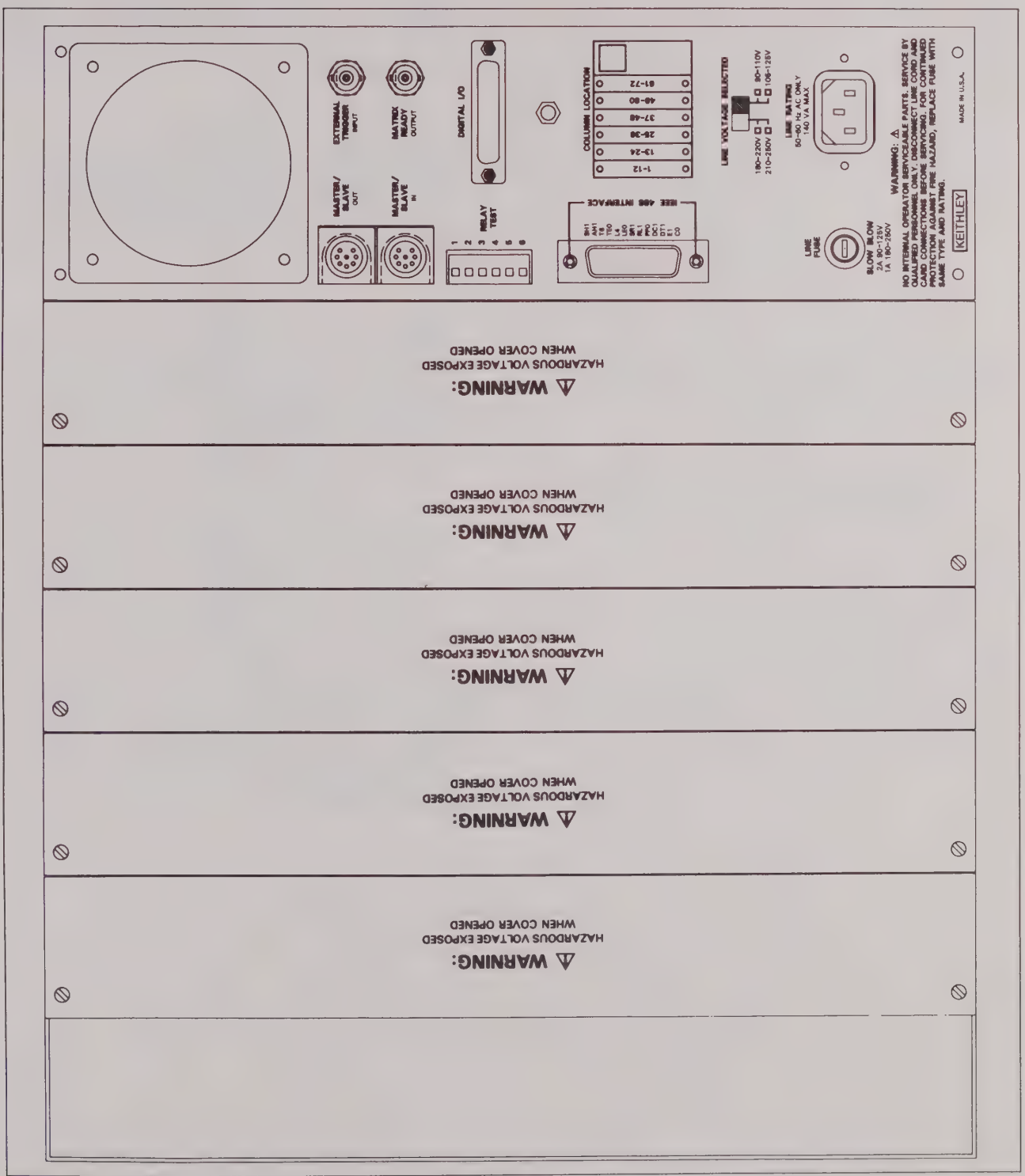


Figure 2-3. Model 707 Rear Panel

2.4 INSTALLING AND REMOVING CARDS

Before operating the Model 707 in a test environment, matrix cards (up to six per mainframe) must be installed into the mainframe. Note that matrix cards are not necessary to program setups. Setups for master/slave configurations can be programmed as long as the MASTER/SLAVE OUT to MASTER/SLAVE IN loop connections are present. (See paragraph 2.6.2.)

WARNING

Turn off mainframe power and disconnect the line cord before installing or removing cards.

Install a card in the Model 707 as follows, using Figure 2-4 as a guide. Instructions specific to each card can be found in the appropriate card manual.

CAUTION

Do not touch the card surfaces, connectors, or components to avoid contamination that could degrade card performance.

1. Ensure that the access door on top of the mainframe is fully closed and locked down. (The bottom side of the access door has card guides.)
2. Remove the slot cover from the desired slot.
3. With one hand grasping the card's handle, and the other supporting its weight, line up the card with the card guides in the slot. Ensure that the component side is facing the fan of the mainframe.
4. Slide the card into the mainframe until it is fully seated in the backplane connectors. Finger-tighten the spring-loaded mounting screws at the back of the card to lock it in place.

WARNING

The mounting screws must be secured to ensure a proper chassis ground connection between the card and the mainframe. Failure to properly secure this ground connection may result in personal injury or death due to electric shock.

NOTE

Some cards have connectors that are inaccessible once the card is fully inserted into the mainframe (e.g., the quick disconnect terminal blocks on Model 7071 cards). In these cases, connect wires to the row and column terminal blocks before seating it in the backplane connectors.

The SMB coax jumpers used between Model 7072 cards do not have to be installed before the cards are inserted. Use the access door on top of the mainframe for this purpose. (Because of the access door, the Model 7079 slide rack kit is recommended for rack-mounted units.)

5. To remove a matrix card, first turn off the mainframe and disconnect the line cord. Ensure no voltage is applied from the user's circuit. Remove any internal cabling between cards through the unit's access door. Loosen the spring-loaded mounting screws and pull out the card by its handle.

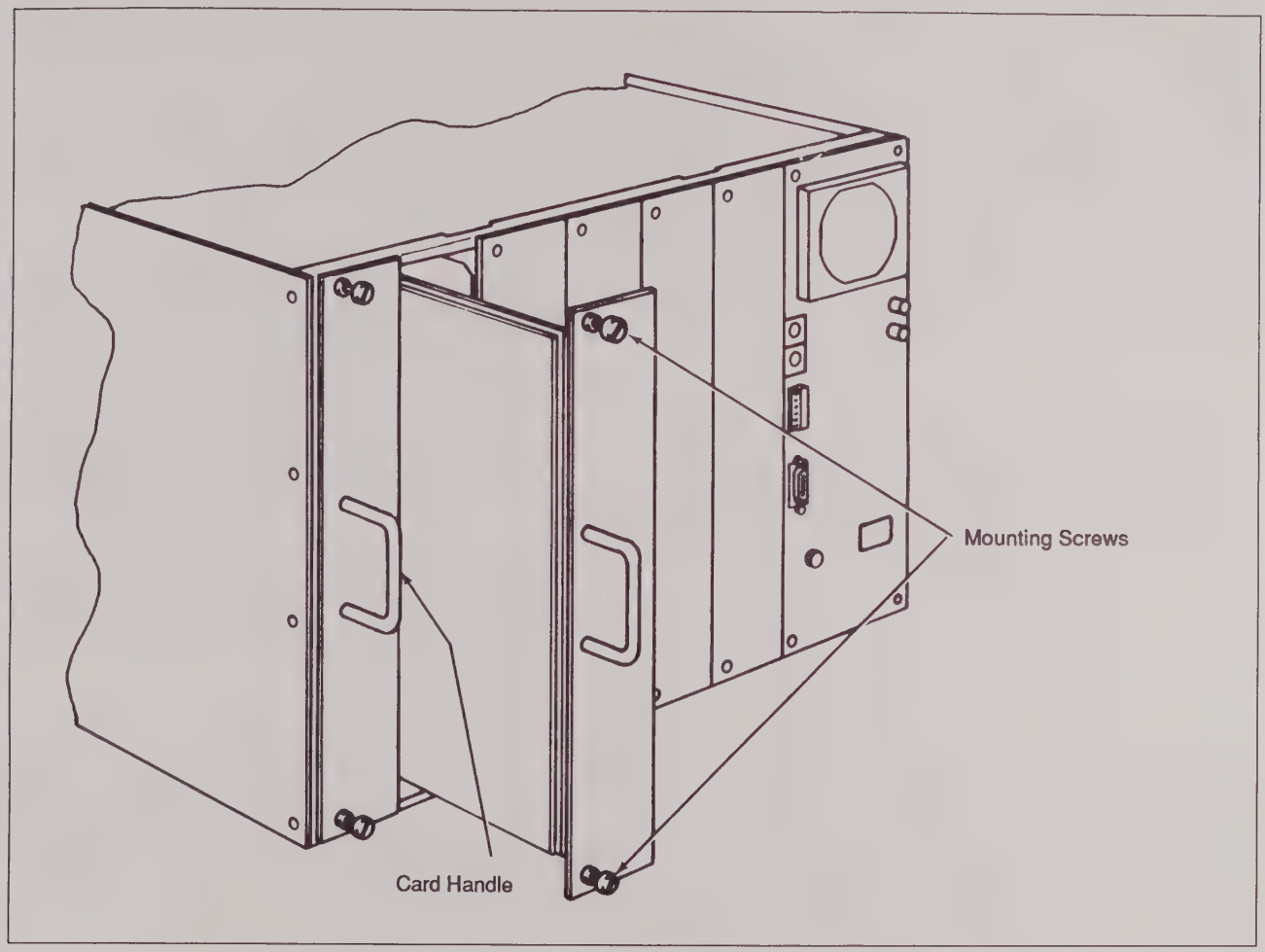


Figure 2-4. Installing a Matrix Card

2.5 CARD CONNECTIONS

Each card designed for the Model 707 is configured as an 8-row by 12-column matrix. The rows are lengthened by adding columns from other cards (of the same model number). Connections for row expansion are usually internal to the mainframe, either through the analog backplane buses or with user-installed jumpers, depending on the card model. Rows can also be expanded across mainframe boundaries, either in a master/slave or stand-alone/stand-alone configuration. In a master/slave configuration of up to five mainframes, the rows are extended to 360 columns maximum. (Paragraph 2.6 describes master/slave expansion.)

Expansion of rows leads to a long, narrow matrix. If your application requires few instruments and many DUTs, connect the instruments to rows (up to 8) and the DUTs to columns (up to 72 with 6 cards). This connection scheme is optimum because the row-column path has only one crosspoint, as shown in Figure 2-5.

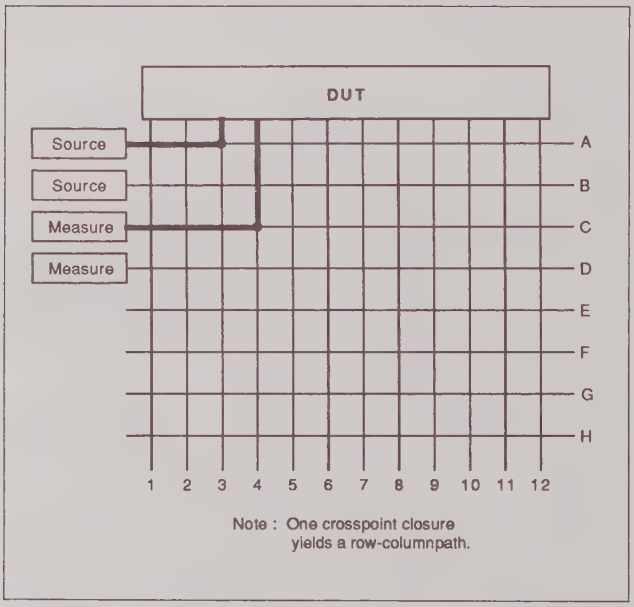


Figure 2-5. Connecting Instruments to Rows

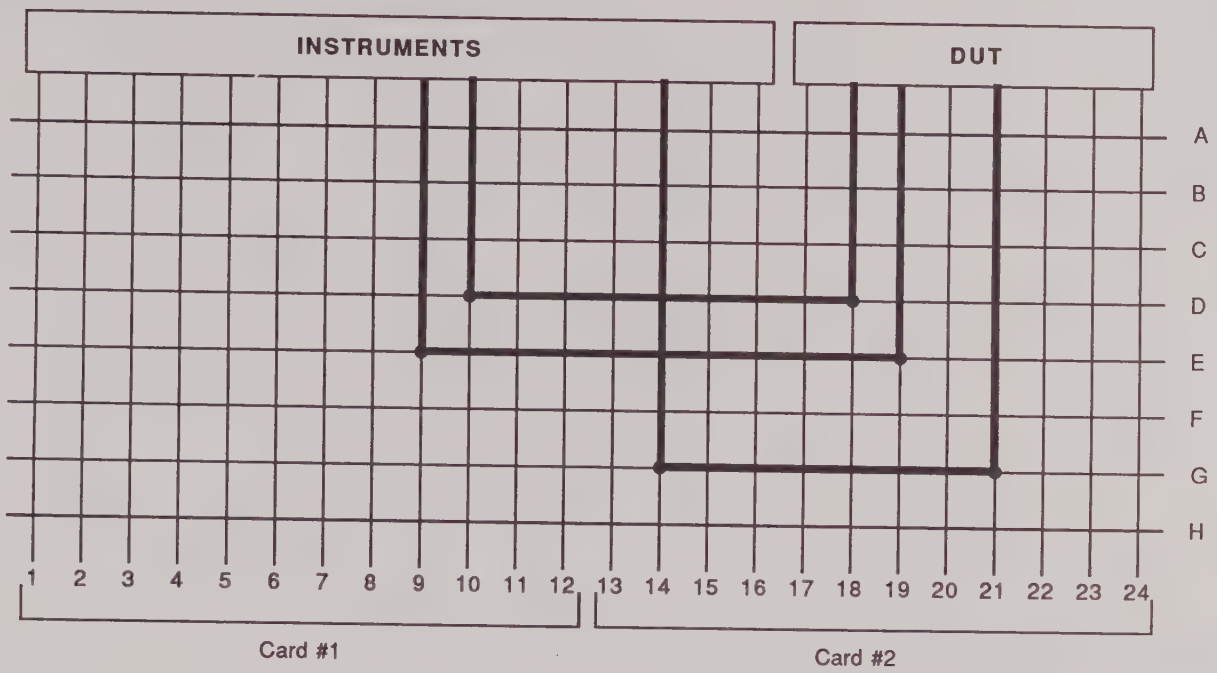
Selecting the row connections for instruments is important with cards designed for multiple applications. Using the Model 7072 as an example, the recommended connections are as follows:

- Rows A and B (low current) - Picoammeters, electrometers.
- Rows C through F (general purpose) - DMMs, sources.
- Rows G and H (C-V characteristics) - C-V analyzers.

An alternate connection scheme of the long, narrow matrix has all connections on the columns, both instruments and DUTs. This is done when the series of tests requires a large number of instruments and DUTs, with only a few signals for each test. As seen in Figure 2-6, with two cards, two crosspoint relays must be closed to complete a path from column-column (a safety benefit when sourcing). Paths with multiple crosspoints have additional path resistance and contact potential than single crosspoint paths.

Crosspoint programming becomes more complex with column-column paths because of the number of possible paths for large matrices and the choice of rows to complete the path. (See Table 2-1.)

The row completion choice for column-column paths on multiple application cards follows the recommendations given previously for row-column paths. That is, with a Model 7072 card, close a crosspoint relay in row A or B for low current applications, row C, D, E, or F for general purpose switching, and row F or G for C-V switching.



Note : Two crosspoint closures yield a column-column path.

Figure 2-6. Connecting Instruments to Columns

Table 2-1. Row-Column and Column-Column Paths

Connection Scheme	Crosspoints per Path	Possible Paths for 8 Rows by 12 Columns	Possible Paths 8 Rows by 72 Columns
Row-Column	1	96	576
Column-Column	2	66	2556

Notes

1. The crosspoints per path do not take into account any isolator relays that may be present on a card.
2. Each column-column path can be through one of eight rows (e.g., connect column 1 to column 2 by closing A1 and A2, or close B1 and B2, etc.).

2.6 EXPANDING MATRIX SIZE

The 8-row by 12-column matrix cards of the Model 707 mainframe are building blocks for larger matrices. Matrix expansion is accomplished by two methods:

- Internal to the mainframe - The Model 707 backplane automatically extends rows from other like cards. Special purpose rows (not extended by the backplane) are extended by user-installed jumpers between adjacent cards.
- External to the mainframe - A master/slave connection of up to five mainframes is an extension of the rows (up to 8 rows by 360 columns). Also, individual rows and columns can be connected between cards or between mainframes.

The paragraphs that follow explain matrix expansion in detail.

2.6.1 Single Unit Expansion

Expansions to a single unit are either connections internal to the mainframe or external connections of the cards in the same mainframe.

Internal Expansion and Isolation

Internal expansion is done automatically through the Model 707 backplane. Each of the six mainframe slots has three card edge connectors, as shown in Figure 2-7 and described below:

- Upper connectors (J101-J106) - Consists of two analog buses (pins 1-22 and pins 23-86) to expand card rows.
- Middle connectors (J107-J112, 34-pin connectors) - Consists of a third analog bus to expand card rows.
- Lower connectors (J113-J118, 30-pin connectors) - This is a digital bus for mainframe control of the matrix cards.

The **first analog bus** expands signals HI and LO of four rows. The LO of an individual row surrounds the HI path and is between the adjacent rows, as shown in Figure 2-8. These rows are used for 2-pole, general purpose switching.

The **second analog bus** expands signals HI, LO, and GUARD of eight rows. The GUARD of each row surrounds the HI and LO paths and separates adjacent rows. See Figure 2-9. These rows are used for 3-pole, general purpose switching and when the guard signal needs to be switched.

The **third analog bus** expands eight rows of a signal HI path and a common ground (chassis). The common ground surrounds the HI path and separates adjacent rows, as shown in Figure 2-10. These rows are for 1-pole switching in common ground (high frequency) systems or floating signals (with an additional row for switching low).

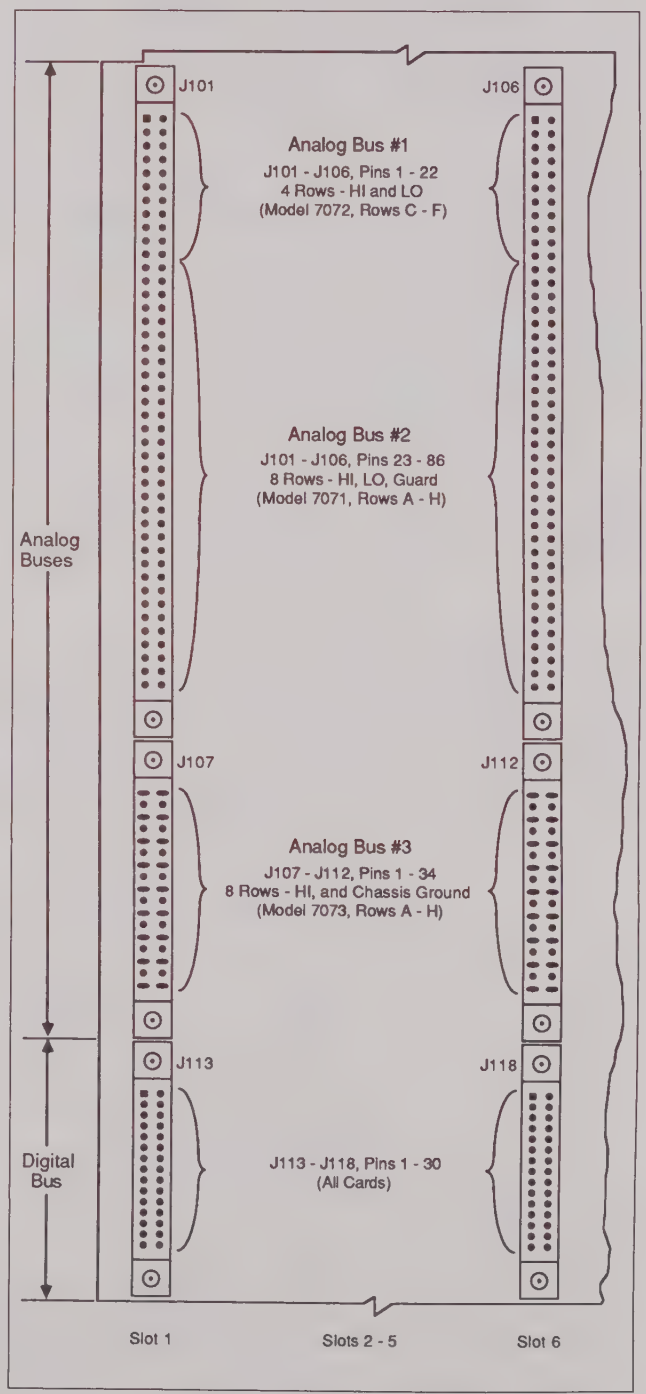


Figure 2-7. Backplane Buses

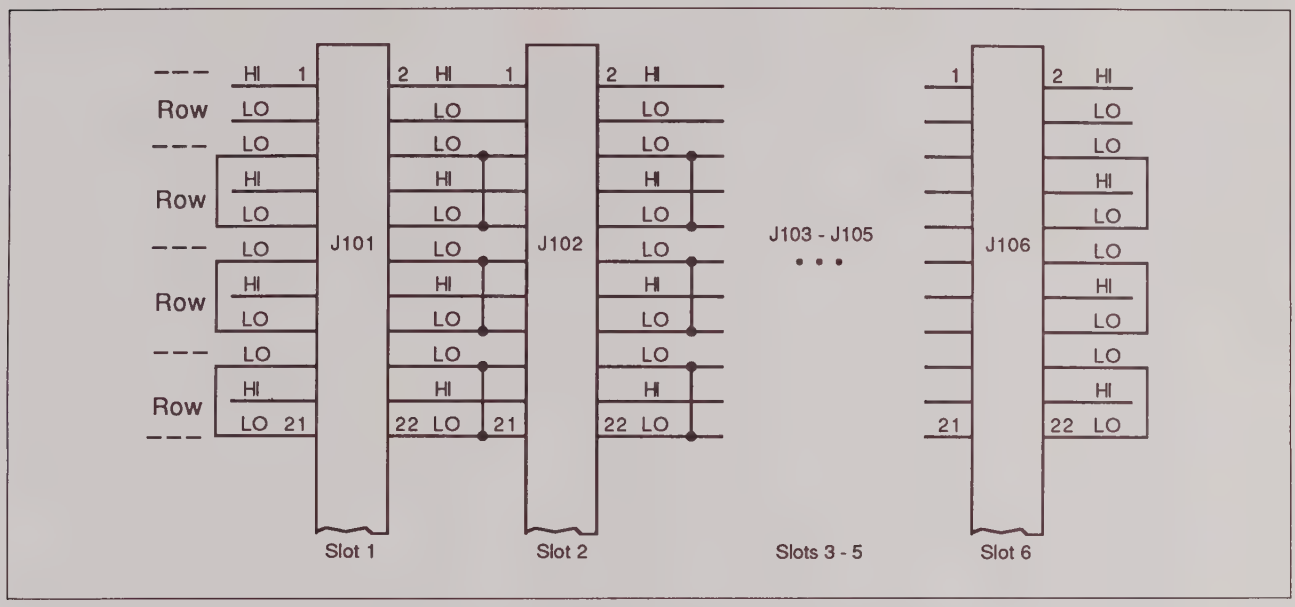


Figure 2-8. Backplane Expansion of Analog Bus #1

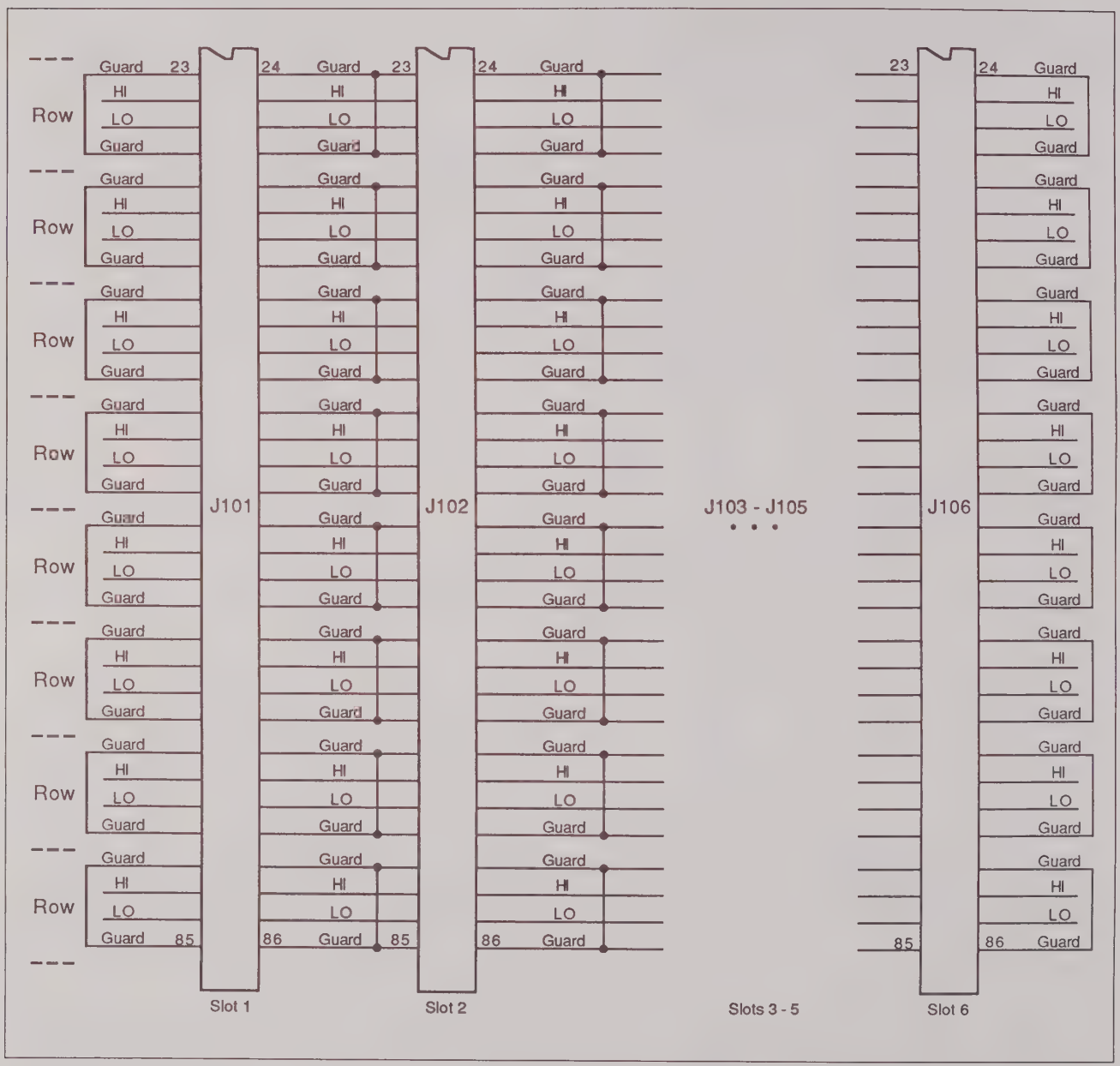


Figure 2-9. Backplane Expansion of Analog Bus #2

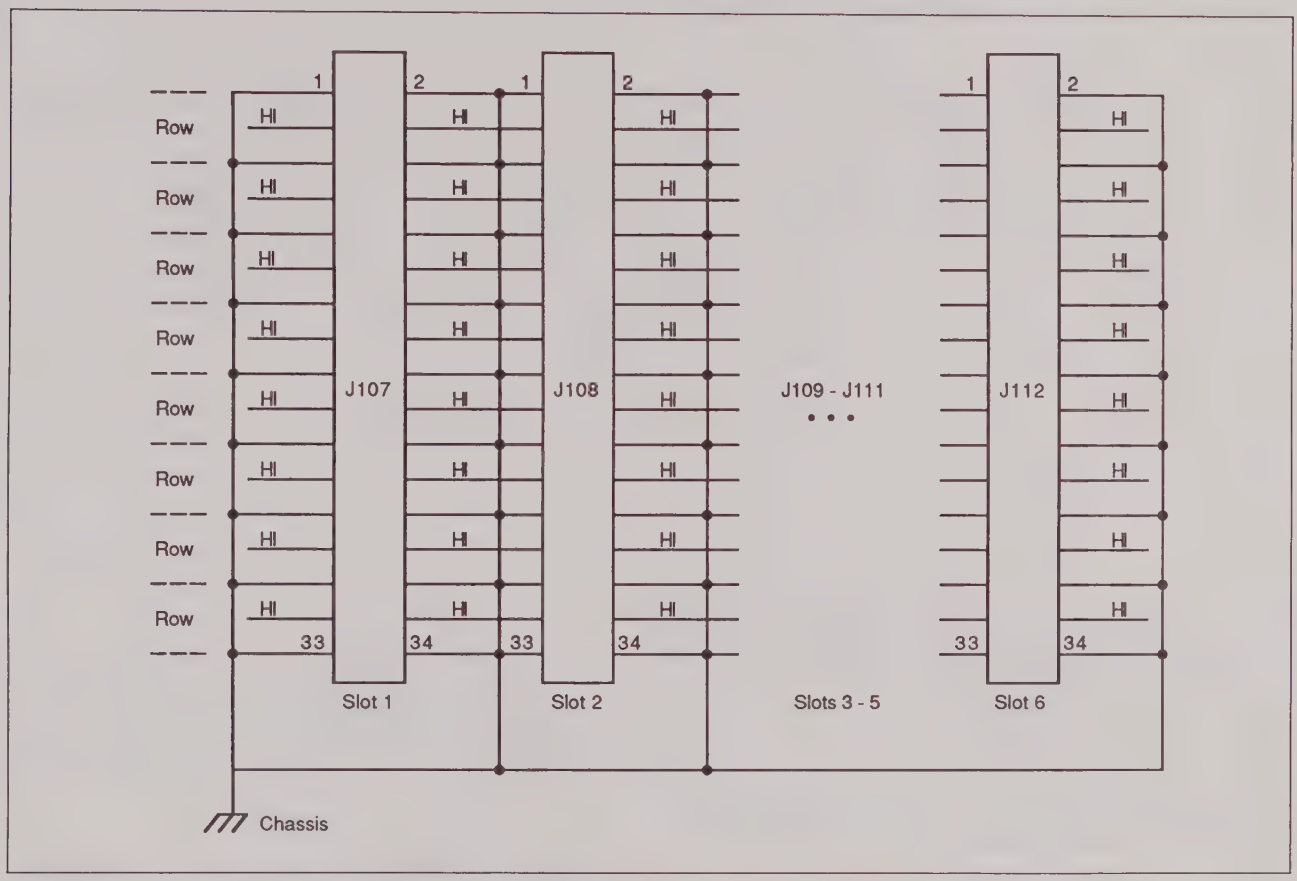


Figure 2-10. Backplane Expansion of Analog Bus #3

Matrix cards for use in the Model 707 have different edge connectors, depending on the signal path configuration of each card model. Analog bus usage by the cards is summarized in Table 2-2. All cards have a connector for the digital bus.

Note that rows A, B, G, and H of Model 7072 cards are expanded with SMB coax jumpers between adjacent cards to lessen signal losses of the low current and C-V rows. The jumpers are internal to the mainframe.

When a mainframe contains different card models, instruments must be connected to each card type because of the differing analog bus usage. An example of this is shown in Figure 2-11.

Table 2-2. Analog Bus Usage

Card	Rows	Analog Backplane Bus
7071	A-H	J101-J106, pins 23-86
7072	C-F	J101-J106, pins 1-22
7073	A-H	J107-J112, pins 1-30

In addition to expanding rows in a mainframe, it is also possible to isolate card rows to some extent. There are factory-installed jumpers on the backplane that can be removed to separate the general purpose rows. These jumpers, which are behind the Model 707 front panel, are between slots 3 and 4 of analog bus #1 (Model 7072 rows C-F) and analog bus #2 (Model 7071 rows A-H). Removing these jumpers effectively separates the mainframe into two 3-slot units. (Jumper removal is described in paragraph 3.13.)

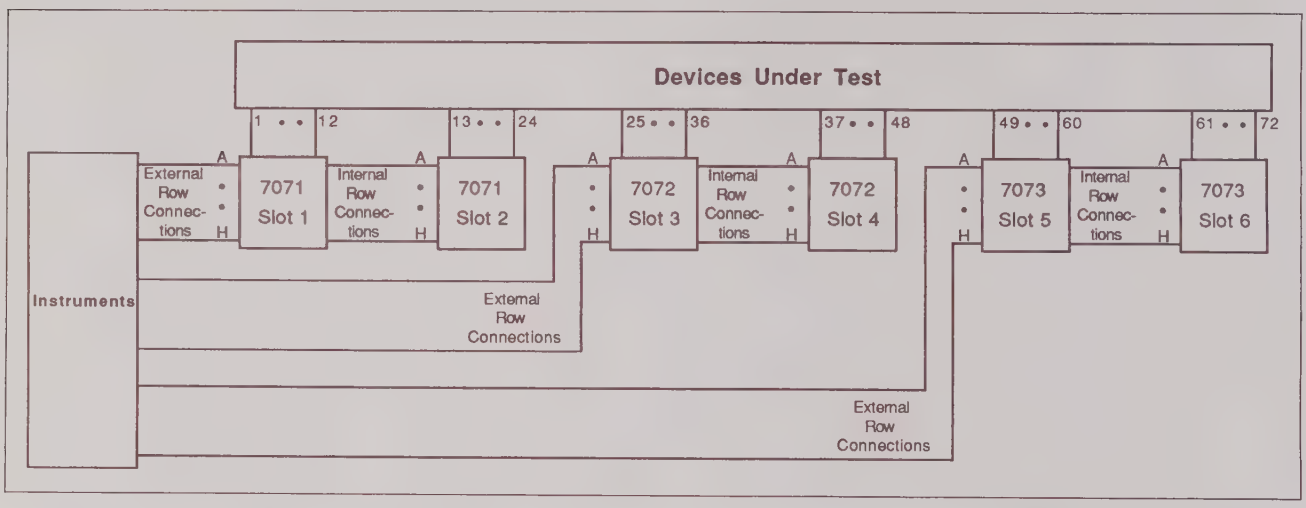


Figure 2-11. Row Connections with Different Card Models

Another isolation method is simply to disconnect the SMB coax jumpers between adjacent Model 7072 cards. These jumpers (for rows A, B, G, and H) are accessed through a door on top of the mainframe.

Jumpers on the Model 7073 card let you selectively expand rows on the backplane to slots on either or both sides, or completely isolate rows from the backplane.

External Expansion

External expansion within a single mainframe is possible with user-installed wiring between rows and columns of like cards. The available accessory cables for external connections are listed in Table 2-3.

CAUTION

Connecting dissimilar cards together often degrades performance of both cards. For example, connecting a Model 7072 to a Model 7073 would degrade low current switching on the 7072 and high frequency switching done with the 7073.

An example of external expansion uses the mainframe as one 6-slot unit and, for some applications, as two 3-slot units. After removing the backplane jumpers, just use external row jumpers between the cards in slots 3 and 4 to select the desired configuration.

External expansion of the cards can also be used to implement a partial matrix. As shown in Figure 2-12 for Model 7071 cards, a column connection is made between the two isolated general purpose backplanes. With the example connections shown, three crosspoints must be closed to source (increasing the safety factor), but only one crosspoint closure is needed to measure (recommended for sensitive instruments).

Table 2-3. Model 707 External Expansion Cables

Model No.	Description	Expansion
7078-KIT 7078-MTC	Mass Terminated Cable Kit Mass Terminated Cable (20 ft.)	7071 rows/columns
7078-TRX-3 7078-TRX-10	3-lug Triax-Triax Cable (3 ft.) 3-lug Triax-Triax Cable (10 ft.)	7072 rows/columns
7051-2 7051-5	BNC-BNC Cable (2 ft.) BNC-BNC Cable (5 ft.)	7073 rows/columns

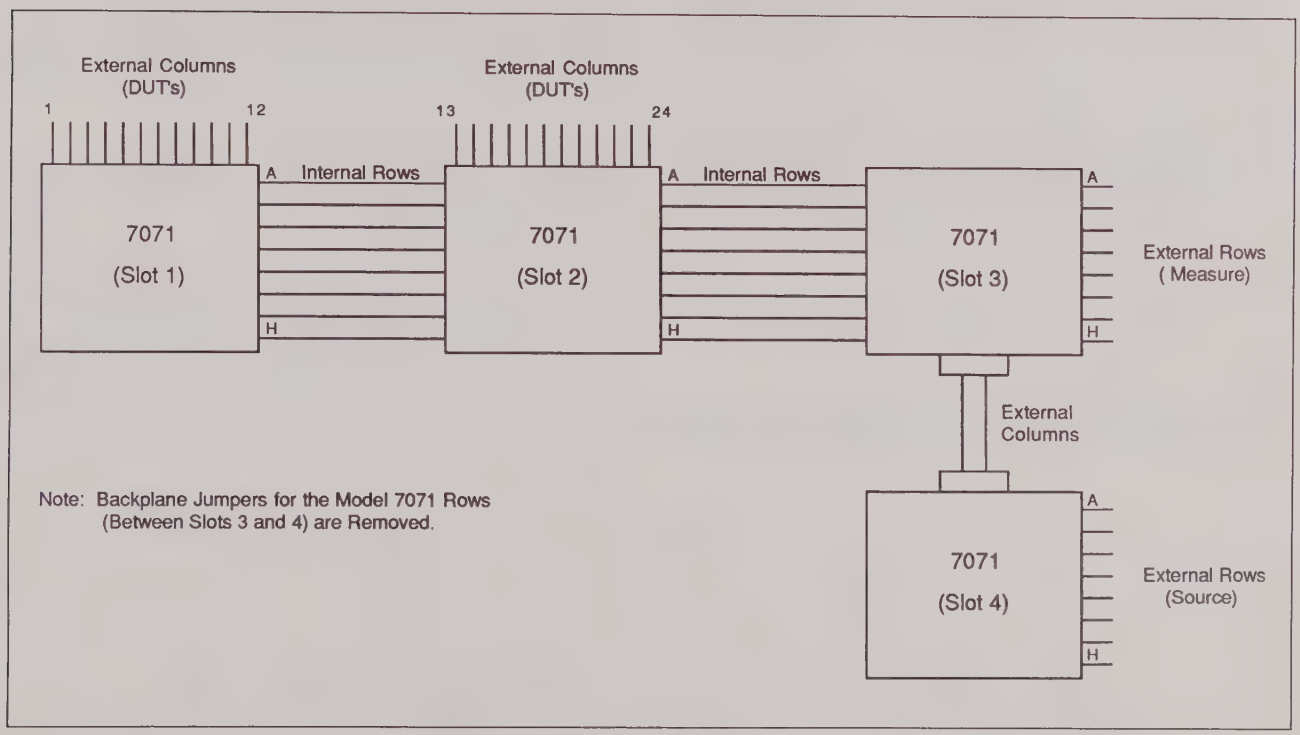


Figure 2-12. Example of Partial Matrix Expansion

2.6.2 Multiple Unit Expansion

Analog Expansion

One method to expand a matrix across mainframe boundaries is to connect cards of separate stand-alone units, either by rows or columns. Each unit has a different IEEE-488 bus address and is programmed independently. The additional digital I/O ports are available for programming.

The analog backplane buses can be expanded between separate mainframes. As seen in Figure 2-13, a mass terminated cable can be used to extend Model 7071 card rows (J101-J106, pins 23-86). This configuration of two stand-alone units is an 8-row by 144-column general purpose matrix, with each mainframe programmed independently.

As an example of expansion by columns, consider a 16-row by 72-column matrix of Model 7072 cards. This can be done by connecting all columns of card #1 in one unit to all columns of card #1 in another unit, and so on for all cards. (Triax T-adapters are used in this example to connect instruments or devices to the columns.)

Analog Expansion and Control Expansion

Another method of expanding a matrix with multiple mainframes is to connect up to five units in a master/slave configuration. This is done by connecting the rows of like cards in separate units, as shown previously in Figure 2-13, but also by connecting the units in a closed loop of DIN cables for communication and control. A master/slave system configuration appears as one unit with expanded card capacity. That is, only the master unit is addressed by the IEEE-488 bus controller.

A master/slave configuration extends matrix rows yielding a long, narrow matrix. Figure 2-14 shows the connections between two units having Model 7071 cards. With five units, the maximum matrix size is 8 rows by 360 columns. Figure 2-15 shows the column assignments for the maximum configuration.

If the mainframes of a master/slave configuration contain different card models, group like cards as much as possible. This will reduce the need to extend the analog buses with external cables.

In some cases, external row expansion is not necessary at all (e.g., one unit only with Model 7071 cards, the second unit only with Model 7072 cards).

The example of Figure 2-16 shows the row expansion, but not the closed loop of DIN cables for master/slave communication and control. The figure shown is actually three matrices (one 8-row by 72-column and two 8-row by 144-column) that are programmed as one 8-row by 360-column matrix.

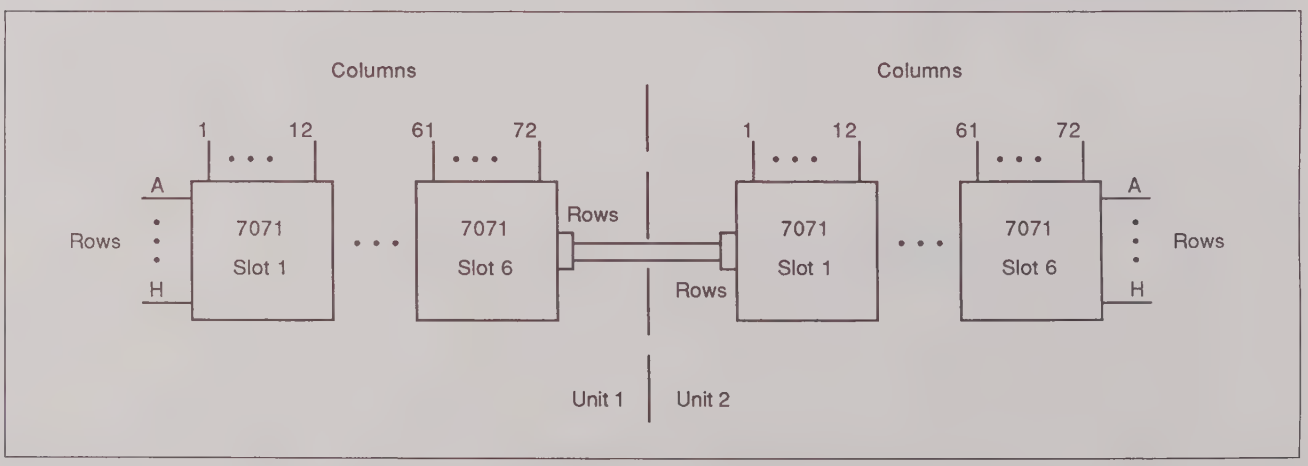


Figure 2-13. Row Connections of Stand-alone Units

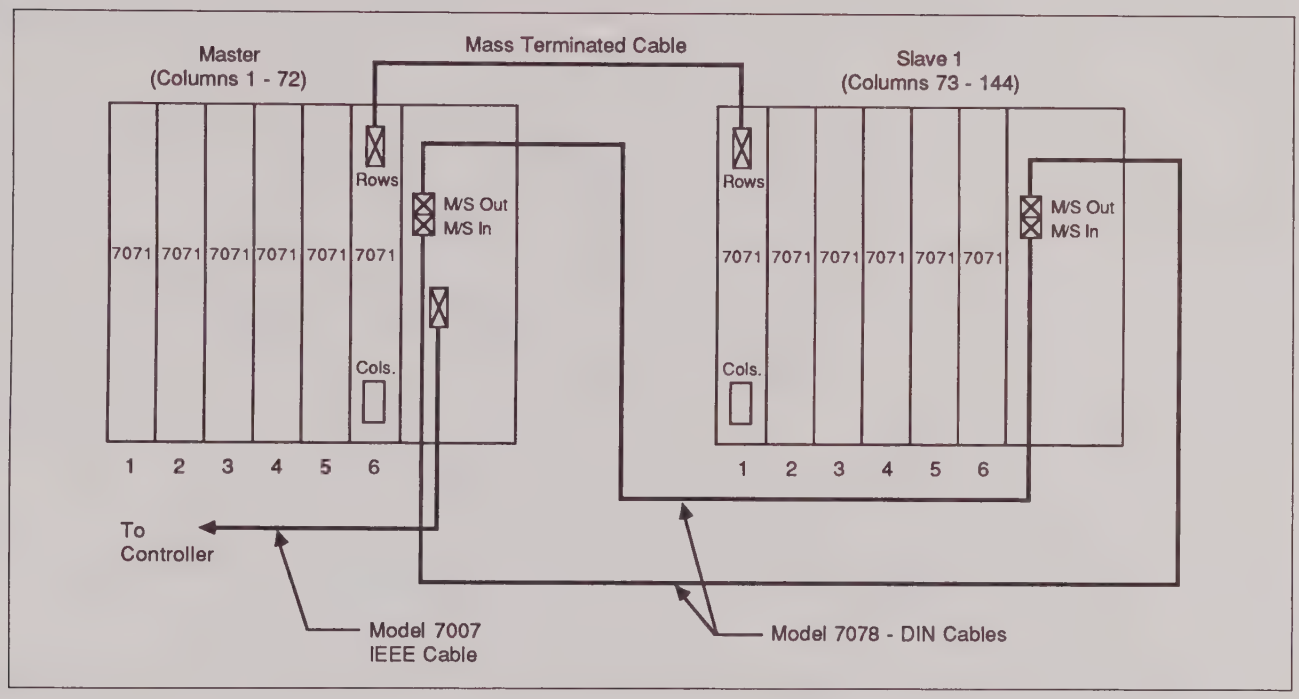


Figure 2-14. Example of Master/Slave Interconnect Cables

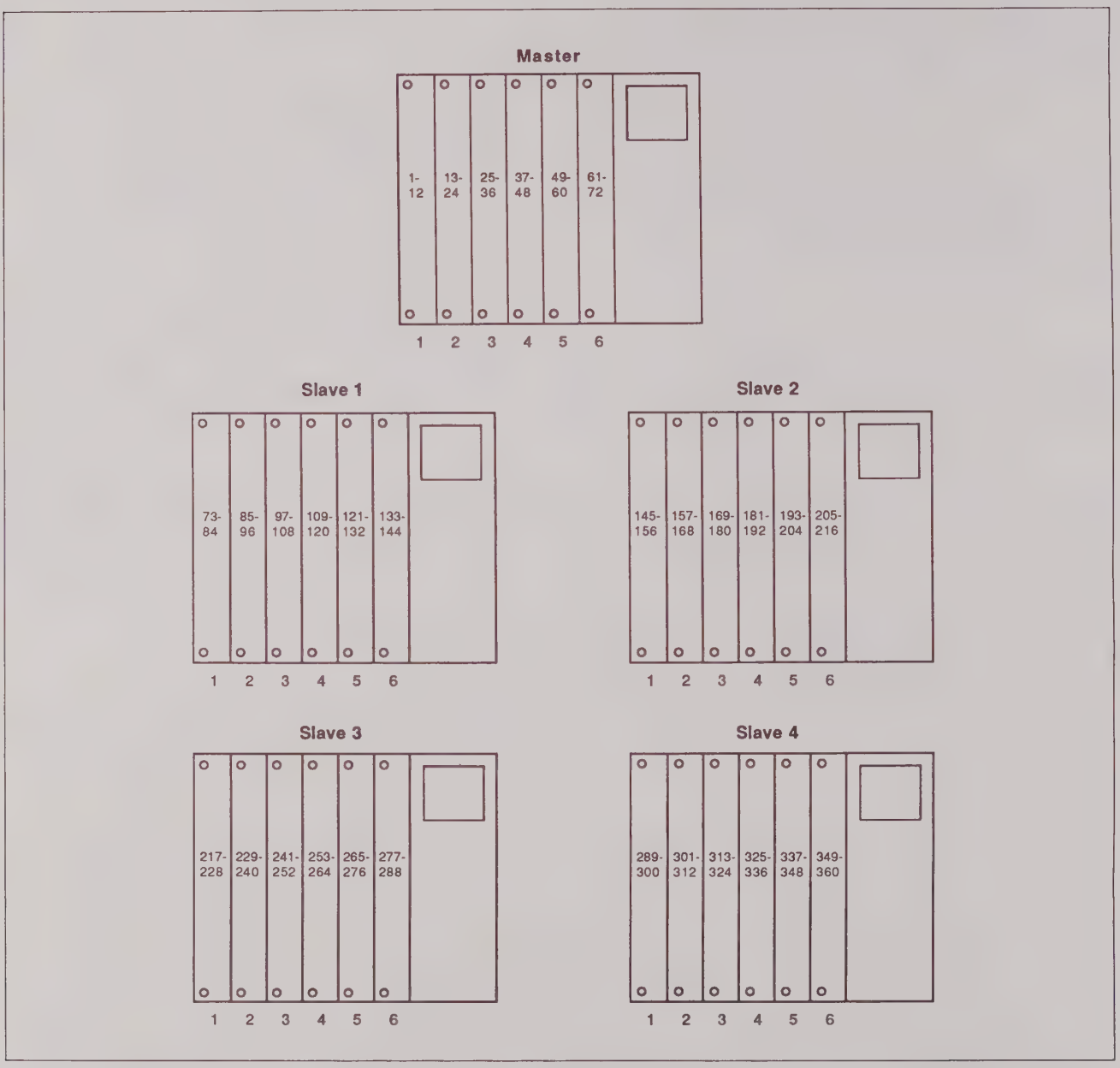


Figure 2-15. Master/Slave Column Locations

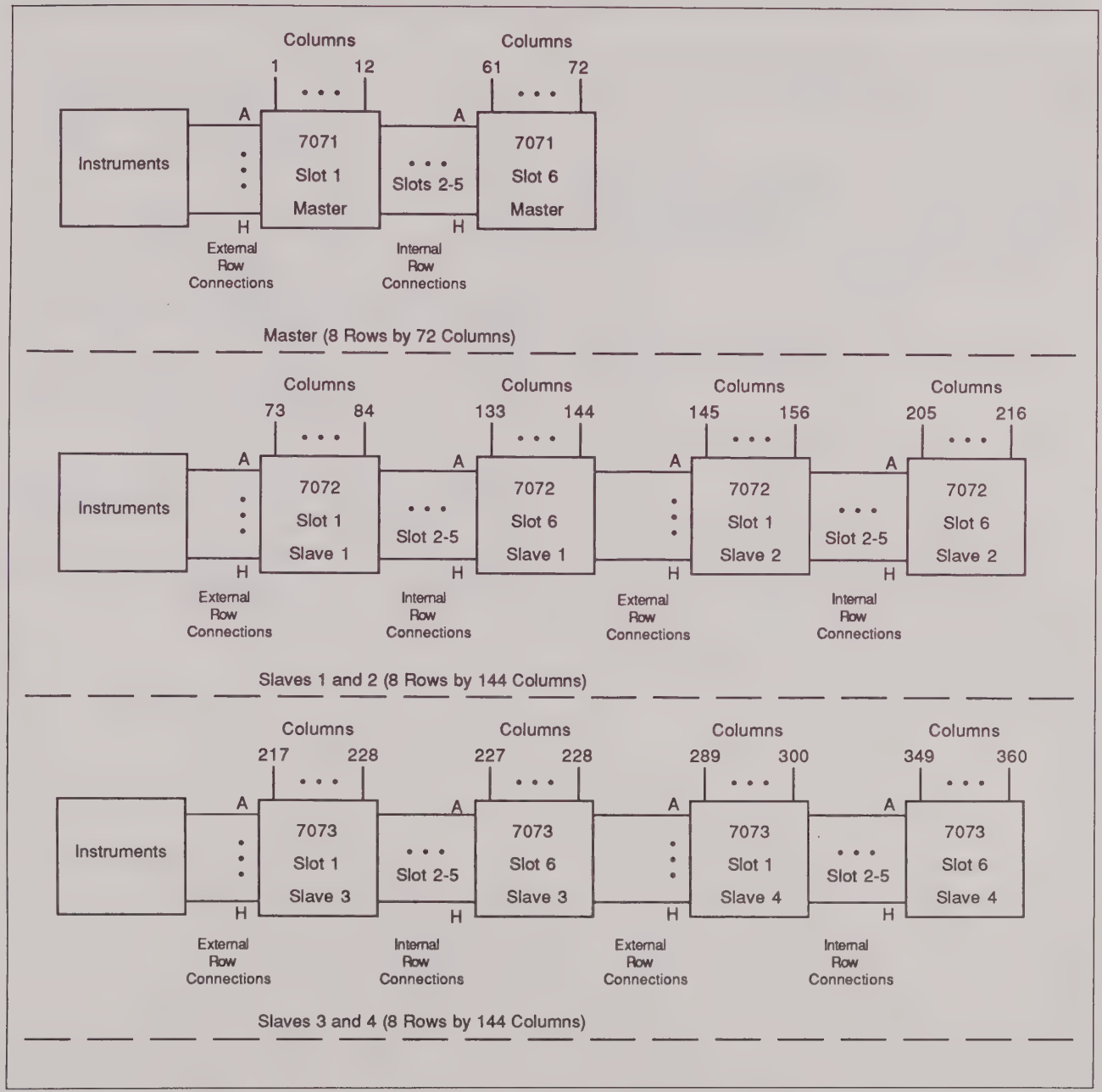


Figure 2-16. Example of Master/Slave Row Expansion

2.6.3 System Expansion Issues

Matrix expansion by Model 707 mainframes affects system specifications and speed. The extent depends on the size and configuration of the switching system.

Within a mainframe, internal row expansion decreases isolation among like cards and increases offset current. Isolation relays (on the Model 7072), backplane jumpers (for general purpose rows), and SMB coax jumpers (on the Model 7072) help lessen these effects.

Expansion of units along rows or columns also degrades the isolation and offset current specifications because of the number of parallel paths and relays on each signal line.

There are several issues that affect system speed, among them are:

- Relay settling time - Each matrix card has a predefined relay settling time (3msec for the 7071, 15msec for the 7072 and 7073). When card types are mixed in a system, the longest settling time is in effect.
- Bus communication - A master/slave setup responds slower to bus commands because all communication is through the master unit and the data transmission among the units is verified with handshaking. Table 2-4 compares some typical times.

Table 2-4. Response Time Comparisons

Action	Stand-alone	Master with 4 Slaves
Respond to bus command to close single relay	<15ms	<55ms
Download one setup to 707	60ms typical	—

2.6.4 Documenting System Configuration

With the connection flexibility of the matrix topology and the expansion/isolation options of the Model 707, it is important to document the system configuration.

An example table for tracking card connections and expansion is shown in Table 2-5. Use the top portion of the table to note system operation and size, the FROM/TO portion to list card row and column connections, and the lower portion for notes concerning expansion and operation (e.g., make/break and break/make rows).

Table 2-5. Model 707 Card Configuration

Slot _____		Model _____
Mainframe:	Stand-alone ____ Master _____	
	Slave1 _____ Slave2 _____ Slave3 _____ Slave4 _____	
System Size: ____	rows _____ columns _____ IEEE Address _____	
FROM (Instrument connection or DUT pin)	External Card Connection	TO (Instrument connection or DUT pin)
	Row A	
	B	
	C	
	D	
	E	
	F	
	G	
	H	
	Column 1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	11	
	12	
Expansion:		
—Backplane bus (rows)		—SMB coax jumpers (rows)
—Point to point wiring (rows/cols.)		—Mass terminated cable (rows/cols.)
—BNC coax cable (rows/columns)		—Triax cable (rows/cols.)
Notes:		

2.7 BASIC SWITCHING OPERATION

The following paragraphs will take you through a simple, general, step-by-step procedure to edit a matrix setup, store it in memory, and send the setup to the relays. Although the steps are described with front panel operations, the procedure can be performed over the IEEE-488 bus. (An example program showing this is given in paragraph 4.2.) Even with no instruments or DUTs connected to the matrix cards, the procedure will still have instructional benefits.

See Section 3 for more operation details, including master/slave configurations.

2.7.1 Powerup

Check that the instrument is set to correspond to the available line voltage. The line voltage switch is located on the rear panel. If the switch is set to the correct position, connect the instrument to a grounded AC outlet using the supplied power cable and turn on the unit.

CAUTION

If the switch setting does not correspond to the available line power, do not change the switch setting and power up the unit as the line fuse will probably blow. Instead, proceed to paragraph 6.2 for the line voltage selection procedure.

The Model 707 will perform a powerup self-test to check ROM, RAM, card configuration, stored setups, master/slave loop, indicators, and displays. It will then display the software revision level and IEEE-488 bus address.

When the self-test has completed, the Model 707 is configured with:

- All relays opened.
- RELAYS indicator lit (crosspoint display shows current relay setup).
- RELAY STEP to 000 (a pseudo setup memory that is cleared at powerup and sent to the relays).
- MEMORY STEP to 001.

Other powerup defaults are detailed in paragraph 3.3.

2.7.2 Selecting Make/Break and Break/Make Rows

Select make-before-break, break-before-make, or don't care operation for the rows. The selections will be in effect for all relay switching, even if a stored setup is not used. (As a general rule, use make/break operation for current sources and break/make for voltage sources.)

Use the data entry keys to select a row, then press MAKE/BREAK or BREAK/MAKE to toggle the state. (Selecting one state for a row de-selects it for the other.) This operation can also be performed with the light pen by using it to turn on/off the MAKE/BREAK and BREAK/MAKE LEDs.

2.7.3 Modifying a Relay Setup

Perform the following steps to edit a matrix setup.

Step 1: Select a Stored Setup

If you want to modify setup #1, just press the MEMORY key. The MEMORY indicator will light. To select another setup (up to location 100), use the numeric data entry keys (leading zeros are not necessary), then press the MEMORY key.

Step 2: Modify the Displayed Setup

Use the data entry keys to select a crosspoint address (A1 through H72), then press the OPEN or CLOSE key. Keystrokes will be shown on the alphanumeric display and the CROSSPOINT DISPLAY MODIFIED indicator will light.

If you have the optional light pen, toggle the state of a crosspoint LED by holding the light pen perpendicular to and touching the front panel overlay and pressing the light pen button.

Continue editing with the front panel keys or light pen until the crosspoint display shows the desired configuration.

2.7.4 Storing Setup and Sending to Relays

The following steps detail front panel operations necessary to store and use the modified setup data.

Step 1: Storing Setup in Memory

To store the modified setup at the location shown in the MEMORY STEP field, just press the COPY DISPLAY→MEMORY key. This action overwrites the old setup data at that location with the newly modified setup.

To select a different memory location, key in a valid location number, then press the COPY DISPLAY→MEMORY key. The MEMORY STEP field is set to the new location.

Step 2A: Sending Setup to Relays

To make the newly modified setup the current relay setup, just press the COPY DISPLAY→RELAYS key. The relay states will be changed to reflect the modified setup data. If the MEMORY LED is lit, the RELAY STEP field will be set equal to the MEMORY STEP field. In effect, this copies a setup from memory to the relays.

Step 2B: Triggering Setup to Relays

If you modified setup #1 and restored it to memory at the same location, a single trigger will copy the setup to the relays. Do this by pressing the trigger SOURCE key, scrolling to the "TRIG ON KEY" display and pressing ENTER. Then press the trigger ENABLE key. Pressing the trigger MANUAL key will copy setup #1 to the relays and set the RELAY STEP field to 001.

SECTION 3
Operation

3.1 INTRODUCTION

This section contains a complete, detailed description of each front and rear panel aspect of the Model 707. The section is arranged as follows:

3.2 **Setup Data Paths:** Describes the paths for setup data within a Model 707 and to/from a bus controller.

3.3 **Power-up Procedure:** Details how to connect the instrument to line power and turn it on, including power-up self-test and default conditions.

3.4 **Displays and Messages:** Covers the uses of the alphanumeric display, crosspoint display, and make/break and break/make row LEDs. Also lists display messages that may be encountered during front panel operations.

3.5 **Selecting Crosspoint Display:** Describes how to select the source of relay setup data (current relay setup or a stored setup).

3.6 **Modifying Crosspoint Display:** Discusses the operations to open/close crosspoint display LEDs.

3.7 **Copying Crosspoint Display:** Describes copying a display to the relays and to memory.

3.8 **Inserting and Deleting Stored Setups:** Covers how to insert a blank setup in memory and how to delete a stored setup from memory.

3.9 **Menu Operations:** Details menu item selection and operation, including digital I/O, external trigger, matrix ready, master/slave, IEEE-488 bus address, relay settling time, card identification, self-test, and factory defaults.

3.10 **Selecting Switching Parameters:** Covers the programmed settling time and make/break, break/make operations.

3.11 **Triggering:** Details selecting the trigger source and describes the operation of the rear panel trigger input and output jacks.

3.12 **Resetting:** Discusses the reset operation of the Model 707.

3.13 **Backplane Jumpers:** Describes how to remove backplane jumpers.

3.2 SETUP DATA PATHS

The design of the Model 707 is optimized for high speed switching of relay setups for matrices with a maximum of 8 rows by 72 columns (one unit) to 8 rows by 360 columns (five units). If no rows are selected for make/break or break/make operation, previously stored setups can be switched to the relays at a rate of up to 200 setups per second.

Besides the triggering of stored setup data to the relays, setup data can be routed to/from the sources and destinations shown in Figure 3-1. The data paths are selected by the front panel or IEEE-488 bus operations listed in Table 3-1.

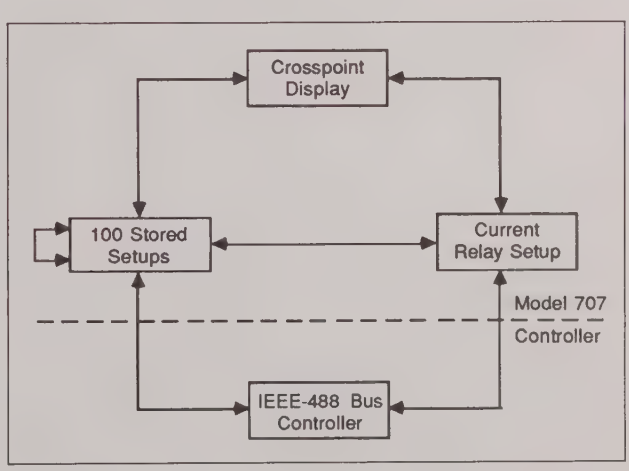


Figure 3-1. Paths for Relay Setup Data

In addition to other front and rear panel operations, this section describes setup data transfers that are performed from the Model 707 front panel. Section 4 will describe the bus operations that transfer setup data.

Table 3-1. Setup Data Paths

Setup Data Path	Action Required
Display→Memory	Front panel keystroke
Display→Relays	Front panel keystroke or an automatic copy (Note 1)
Memory→Display	Front panel keystroke or an automatic operation (Note 2)
Memory→Relays	Bus command or any valid trigger
Memory→Controller	Bus command
Memory→Memory	Bus command
Relays→Display	Front panel keystroke or an automatic operation (Note 3)
Relays→Memory	Bus command
Relays→Controller	Bus command
Controller→Memory	Bus command
Controller→Relays	Bus command

Notes:

1. Generation of the automatic copy is selected by a front panel key. (AUTOMATIC LED is lit.)
2. The automatic operation is generated if the displayed setup has been changed by a bus command and has not been modified from the front panel. (MEMORY LED is lit.)
3. The automatic operation is generated if the displayed setup has been changed by a trigger or bus command and has not been modified from the front panel. (RELAYS LED is lit.)
4. Controller modifications to setups are reflected on the crosspoint display if the affected setup is currently being displayed.
5. Front panel keystrokes can be generated by bus commands.

3.3 POWER-UP PROCEDURE

The steps in the following paragraphs take you through the basic procedures for selecting the line voltage, connecting the instrument to line power, and turning on the instrument.

3.3.1 Line Voltage Selection

The Model 707 can be operated from either 105-125V or 210-250V, 50 or 60Hz sources. The transformer can be rewired at the factory for 90-110V and 180-220V ranges. The instrument was shipped from the factory set for an operating voltage that corresponds to the normally available line voltage in your area.

CAUTION

Do not operate the instrument on a line voltage outside the indicated range, or instrument damage can occur.

To check the line voltage setting, look at the position of the slide switch located on the rear panel (see Figure 3-2). If the switch is in the wrong position, the line fuse will probably have to be replaced with one that has a different rating. Refer to paragraph 6.2 in the maintenance section for the line voltage selection procedure.

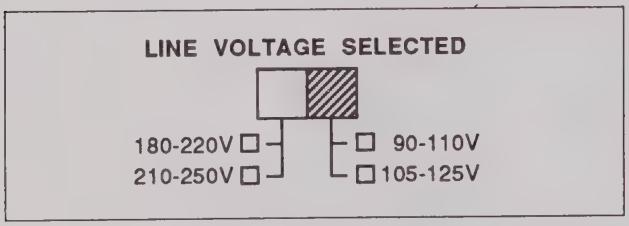


Figure 3-2. Line Voltage Switch

3.3.2 Line Power Connections

Using the supplied power cord, connect the instrument to an appropriate 50 or 60Hz ac power source. The female end of the cord connects to the ac receptacle on the rear panel of the instrument. The other end of the cord should be connected to a grounded ac outlet.

WARNING

The Model 707 must be connected to a grounded outlet to maintain continued protection against possible shock hazards. Failure to use a grounded outlet may result in personal injury or death due to electric shock.

3.3.3 Power Switch

To turn on the power, simply push in the front panel POWER switch. Power is on when the switch is at the inner (1) position. To turn power off, press POWER a second time.

3.3.4 Power-up Self-test and Messages

During the power-up cycle, the instrument performs the following tests. The first five operations are transparent to the user unless an error occurs.

1. A checksum test is performed on ROM and a read/write test on RAM. If an error is found, the self-test continues and the unit displays either ROM FAIL or RAM FAIL when the test has completed. You can override either type of error with a front panel keypress. The Model 707 will attempt normal operation.

NOTE

If a problem develops while the instrument is still under warranty (less than one year from shipment date), return it to Keithley Instruments, Inc. for repair. For units out of warranty, refer to Section 6, Maintenance.

2. The Model 707 reads identity information from each card and performs a checksum test on the data. If the checksum test fails on one or more matrix cards, the instrument displays CARD ID ERROR and lights all crosspoint LEDs of that card. Any keypress will allow the unit to continue. An empty slot will not produce an error.
3. A checksum test is performed on all setups in memory. If the instrument detects a checksum error in one or more stored setups, it displays the message SETUP ERROR and clears the crosspoints bits of the setup(s) in error. The message remains displayed until a key is pressed.

NOTE

The SETUP ERROR message may be an indication of a low battery. Cycle power off and on. If the message reappears, see paragraph 6.6 for battery replacement procedure.

4. The present card configuration (i.e., which cards are installed in which slots) is compared with the unit's previous configuration. If there is a change, the 100 setups in memory are reformatted. (The front panel display is blanked out during this time.) Crosspoint closures are not affected, just the way a setup is stored for the different cards.
5. If the unit was previously programmed as a stand-alone or slave unit, it powers up as a stand-alone. If the unit was programmed as a master the last time it was on, it checks for additional units in a serial looped configuration and tries to make them slave units. (Refer to paragraph 3.3.6 for information concerning turning on a master/slave configuration.)

   The message M/S ERROR is displayed if there is not a closed loop (the Model 707 can be looped back to itself). Any keypress or IEEE-488 bus operation will allow the unit to continue as a stand-alone unit.
6. The instrument performs the display test, where it lights all segments of the alphanumeric display, all crosspoint LEDs, and all other LED indicators. Then it briefly displays the software revision level and the programmed primary IEEE-488 address as in this example:

   A01 IEEE 18

   Knowing the software revision level is useful when discussing problems with Keithley Instruments. In this example, the factory default primary IEEE-488 address is displayed. The actual address depends on the programmed value.

3.3.5 Power-up Configuration

After the power-up tests and display messages are completed, the Model 707 assumes specific operating states:

- All relays are opened.
- The RELAYS indicator is lit (crosspoint display shows current relay setup).
- The RELAY STEP field is set to 000 and the MEMORY STEP field is set to 001.
- Triggers are disabled.

Table 3-2 summarizes the power-up configuration for the unit. The entire power-up process takes approximately five seconds to complete.

Table 3-2. Power-up, Reset, and Factory Defaults

Parameter	Power-up/Reset Default	Factory Default
Relays	All opened	All opened
Stored Setups	Unchanged	All cleared
RELAY STEP	000	000
MEMORY STEP	001	001
Digital Output	000	000
External Trigger	Falling edge	Falling edge
Matrix Ready	Active low	Active low
Master/Slave	Unchanged (if successful)	Unchanged
IEEE-488 Address	Unchanged	18
Programmed Settling Time	0msec	0msec
Make/Break Rows	Unchanged	None selected
Break/Make Rows	Unchanged	None selected
Trigger Enable	Disabled	Disabled
Trigger Source	External	External

3.3 POWER-UP PROCEDURE

The steps in the following paragraphs take you through the basic procedures for selecting the line voltage, connecting the instrument to line power, and turning on the instrument.

3.3.1 Line Voltage Selection

The Model 707 can be operated from either 105-125V or 210-250V, 50 or 60Hz sources. The transformer can be rewired at the factory for 90-110V and 180-220V ranges. The instrument was shipped from the factory set for an operating voltage that corresponds to the normally available line voltage in your area.

CAUTION

Do not operate the instrument on a line voltage outside the indicated range, or instrument damage can occur.

To check the line voltage setting, look at the position of the slide switch located on the rear panel (see Figure 3-2). If the switch is in the wrong position, the line fuse will probably have to be replaced with one that has a different rating. Refer to paragraph 6.2 in the maintenance section for the line voltage selection procedure.

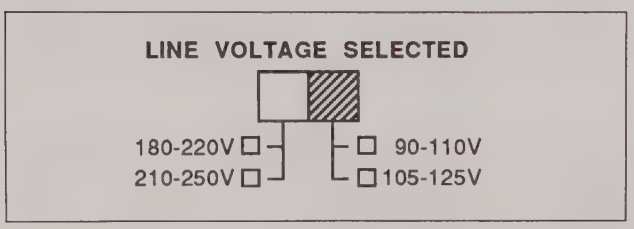


Figure 3-2. Line Voltage Switch

3.3.2 Line Power Connections

Using the supplied power cord, connect the instrument to an appropriate 50 or 60Hz ac power source. The female end of the cord connects to the ac receptacle on the rear panel of the instrument. The other end of the cord should be connected to a grounded ac outlet.

WARNING

The Model 707 must be connected to a grounded outlet to maintain continued protection against possible shock hazards. Failure to use a grounded outlet may result in personal injury or death due to electric shock.

3.3.3 Power Switch

To turn on the power, simply push in the front panel POWER switch. Power is on when the switch is at the inner (1) position. To turn power off, press POWER a second time.

3.3.4 Power-up Self-test and Messages

During the power-up cycle, the instrument performs the following tests. The first five operations are transparent to the user unless an error occurs.

1. A checksum test is performed on ROM and a read/write test on RAM. If an error is found, the self-test continues and the unit displays either ROM FAIL or RAM FAIL when the test has completed. You can override either type of error with a front panel keypress. The Model 707 will attempt normal operation.

NOTE

If a problem develops while the instrument is still under warranty (less than one year from shipment date), return it to Keithley Instruments, Inc. for repair. For units out of warranty, refer to Section 6, Maintenance.

2. The Model 707 reads identity information from each card and performs a checksum test on the data. If the checksum test fails on one or more matrix cards, the instrument displays CARD ID ERROR and lights all crosspoint LEDs of that card. Any keypress will allow the unit to continue. An empty slot will not produce an error.
3. A checksum test is performed on all setups in memory. If the instrument detects a checksum error in one or more stored setups, it displays the message SETUP ERROR and clears the crosspoints bits of the setup(s) in error. The message remains displayed until a key is pressed.

4. The present card configuration (i.e., which cards are installed in which slots) is compared with the unit's previous configuration. If there is a change, the 100 setups in memory are reformatted. (The front panel display is blanked out during this time.) Crosspoint closures are not affected, just the way a setup is stored for the different cards.
5. If the unit was previously programmed as a stand-alone or slave unit, it powers up as a stand-alone. If the unit was programmed as a master the last time it was on, it checks for additional units in a serial looped configuration and tries to make them slave units. (Refer to paragraph 3.3.6 for information concerning turning on a master/slave configuration.)

   The message M/S ERROR is displayed if there is not a closed loop (the Model 707 can be looped back to itself). Any keypress or IEEE-488 bus operation will allow the unit to continue as a stand-alone unit.
6. The instrument performs the display test, where it lights all segments of the alphanumeric display, all crosspoint LEDs, and all other LED indicators. Then it briefly displays the software revision level and the programmed primary IEEE-488 address as in this example:

   A01 IEEE 18

   Knowing the software revision level is useful when discussing problems with Keithley Instruments. In this example, the factory default primary IEEE-488 address is displayed. The actual address depends on the programmed value.

3.3.5 Power-up Configuration

After the power-up tests and display messages are completed, the Model 707 assumes specific operating states:

- All relays are opened.
- The RELAYS indicator is lit (crosspoint display shows current relay setup).
- The RELAY STEP field is set to 000 and the MEMORY STEP field is set to 001.
- Triggers are disabled.

Table 3-2 summarizes the power-up configuration for the unit. The entire power-up process takes approximately five seconds to complete.

Table 3-2. Power-up, Reset, and Factory Defaults

Parameter	Power-up/Reset Default	Factory Default
Relays	All opened	All opened
Stored Setups	Unchanged	All cleared
RELAY STEP	000	000
MEMORY STEP	001	001
Digital Output	000	000
External Trigger	Falling edge	Falling edge
Matrix Ready	Active low	Active low
Master/Slave	Unchanged (if successful)	Unchanged
IEEE-488 Address	Unchanged	18
Programmed Settling Time	0msec	0msec
Make/Break Rows	Unchanged	None selected
Break/Make Rows	Unchanged	None selected
Trigger Enable	Disabled	Disabled
Trigger Source	External	External

3.3.6 Master/Slave Power-up

The power-up sequence for Model 707 mainframes can be summarized as follows:

Each unit connected in the master/slave loop displays M/S LOOP DOWN until all units are powered up.

- Units previously programmed as stand-alones or slaves power up as stand-alones.
- A unit previously programmed as a master powers up as a master and tries to initiate a loop connection. If it is successful, other units in the loop become slaves. If it is not successful, the message M/S ERROR is displayed and the unit reverts to stand-alone operation.

To connect and power up a master/slave configuration for the first time, follow these steps:

1. Connect up to five mainframes in a daisy chain (Master/Slave Out of one unit to Master/Slave In of next unit) as previously shown in Figure 2-15 for two units.
2. Power up each unit. Since there is no master in the loop as yet, all units will power up as stand-alones. The units will display the message M/S LOOP DOWN until all are turned on.
3. From the front panel of the desired master unit, press the MENU key until the alphanumeric display shows:

   STANDALONE

Press one of the SCROLL keys to change the display to MASTER, then press ENTER. This action initiates a loop connection, making this unit the master and the other units slaves, and exits menu mode.

During subsequent power-ups of master/slave configurations, all connected mainframes wait for all units to get power before initializing. Thus, it is not necessary to turn on the master unit last.

CAUTION

When it is necessary to cycle power on a slave unit, turn off all units in the master/slave configuration. This procedure prevents the open communication and control loop from putting the slave unit in an undesirable state.

3.4 DISPLAYS AND MESSAGES

3.4.1 Alphanumeric Display

The alphanumeric display is a 14-character display that can show error messages, informational messages (e.g., menu item parameters), last setup sent to relays, last setup recalled to crosspoint display, trigger source, programmed settling time, and alphanumeric key presses. See Figure 3-3.

The 3-digit RELAY STEP field of the alphanumeric display shows the location of the last setup sent from memory to the relays. A trigger causes the next setup (RELAY STEP +1) to be sent to the relays.

The 3-digit MEMORY STEP field of the alphanumeric display shows the location of the last setup recalled from memory to the crosspoint display.

The 6-digit data entry scratchpad field reflects alphanumeric key presses by the user, such as row and column addresses and setup locations.

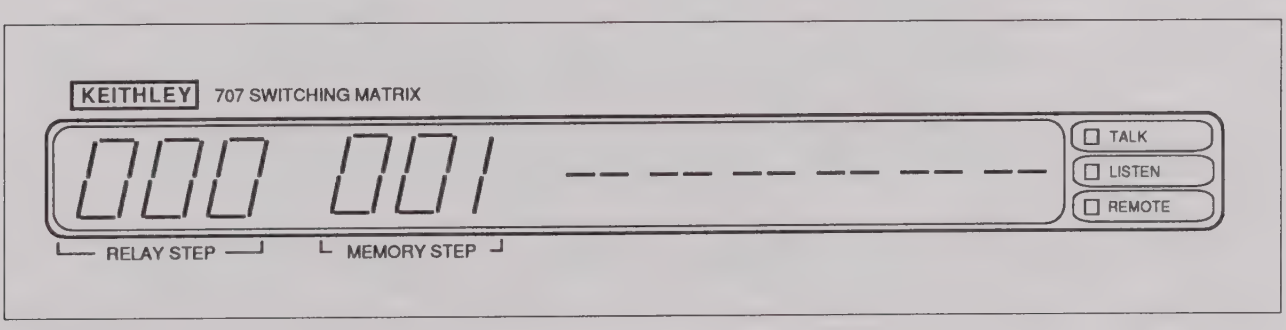


Figure 3-3. Alphanumeric Display

3.4.2 Display Messages

During Model 707 operation and programming, you will encounter a number of front panel messages on the alphanumeric display. Typical messages will be either of error or informational variety, as discussed in the following paragraphs.

Error Messages

Error messages are divided into two categories: those which stay on the display until a keypress or some other operation changes the display, and those which appear for two seconds and then the display returns to its previous state.

Table 3-3 lists Model 707 error messages. Many of these messages are also covered in pertinent paragraphs of the manual. Where applicable, the necessary corrective action is also given in the table.

Informational Messages

Informational messages are included as a programming aid. No corrective action is necessary, but you still may be required to enter a parameter at the prompt. Table 3-4 lists Model 707 informational messages. Again, most of these are covered in other parts of the manual.

Table 3-3. Error Messages

Message	Description	Corrective Action
CARD ID ERROR*	Checksum test failed on one or more matrix cards.	Remove card identified by all crosspoint LEDs lit.
IDDC	Invalid device-dependent command.	Send only valid commands (see Section 4).
IDDCO	Invalid device-dependent command option.	Send only valid command options (see Section 4).
INVALID INPUT	Invalid crosspoint address, setup location, make/break or break/make row, or parameter out of range.	Enter valid data.
LIGHT PEN????	Light pen button pressed when pen was not pointed at crosspoint LED or make/break or break/make LED.	Press button with pen perpendicular to LED.
M/S ERROR*	Error in master/slave communication loop (overrun, parity, framing, count imbalance, or time-out).	Check for a closed loop of MASTER/SLAVE OUT to MASTER/SLAVE IN.
M/S LOOP DOWN	One or more units connected in master/slave loop are not powered up.	Turn on all units or reconfigure master/slave loop.
NOT IN REMOTE	"X" character received over IEEE-488 bus but Model 707 is not in remote.	Put Model 707 in remote.
RAM FAIL*	Self-test detected error in RAM.	See troubleshooting in Section 6.
ROM FAIL*	Self-test detected checksum error in ROM.	See troubleshooting in Section 6.
SETUP ERROR*	Self-test detected checksum error in stored setup. Battery may be low.	Affected setup is cleared, then Model 707 proceeds normally.
TRIG OVERRUN	An additional trigger was received before the Model 707 asserts the READY signal.	Check the READY bit in the serial poll byte.

* Message remains displayed until next operation.

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The power-up sequence for Model 707 mainframes can be summarized as follows:

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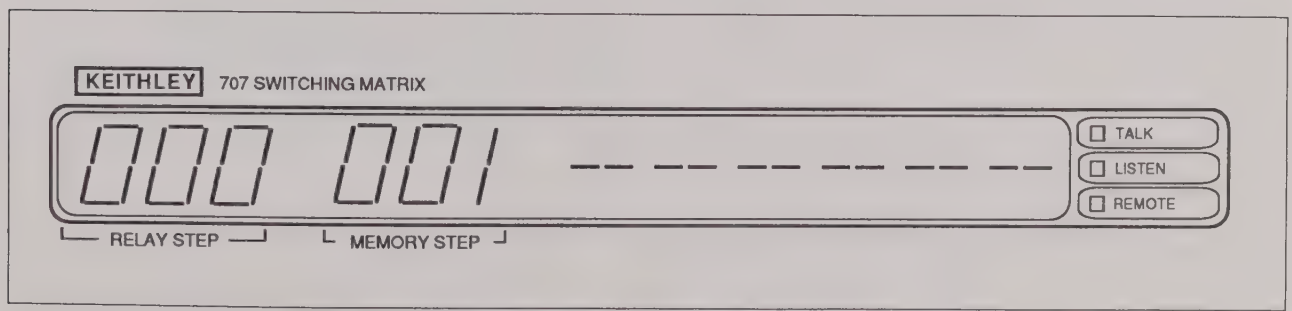

Figure 3-3. Alphanumeric Display

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INVALID INPUT	Invalid crosspoint address, setup location, make/break or break/make row, or parameter out of range.	Enter valid data.
LIGHT PEN????	Light pen button pressed when pen was not pointed at crosspoint LED or make/break or break/make LED.	Press button with pen perpendicular to LED.
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M/S LOOP DOWN	One or more units connected in master/slave loop are not powered up.	Turn on all units or reconfigure master/slave loop.
NOT IN REMOTE	"X" character received over IEEE-488 bus but Model 707 is not in remote.	Put Model 707 in remote.
RAM FAIL*	Self-test detected error in RAM.	See troubleshooting in Section 6.
ROM FAIL*	Self-test detected checksum error in ROM.	See troubleshooting in Section 6.
SETUP ERROR*	Self-test detected checksum error in stored setup.	Affected setup is cleared, then Model 707 proceeds normally.
TRIG OVERRUN	An additional trigger was received before the Model 707 asserts the READY signal.	Check the READY bit in the serial poll byte.

* Message remains displayed until next operation.

Table 3-4. Informational Messages

Message	Key(s)	Description
IN 255 OUT 000	MENU	Digital input status and digital output parameter (decimal values).
EXT TRIG FALL	MENU	Falling edge external trigger pulse.
EXT TRIG RISE	MENU	Rising edge external trigger pulse.
MATRIX RDY LO	MENU	Matrix Ready pulse active low.
MATRIX RDY HI	MENU	Matrix Ready pulse active high.
STANDALONE	MENU	Stand alone operation of Model 707.
MASTER	MENU	Master unit in master/slave configuration.
IEEE-488 18	MENU	IEEE-488 bus address of 18.
HWSETL 015 mS	MENU	Longest relay settling time of present card configuration (Model 7073 is shown).
1 7071	MENU	Card configuration by slot and model number (Model 7071 in slot 1 is shown).
SELF TEST	MENU	Item to select self-test execution.
FACTORY INIT	MENU	Item to select factory defaults (setups cleared).
SETL 00000 mS	SETTLING TIME	Programmed settling time (added to relay settling time).
TRIG ON EXT	SOURCE	External trigger pulse triggering.
TRIG ON KEY	SOURCE	Front panel key triggering.
TRIG ON TALK	SOURCE	IEEE talk command triggering.
TRIG ON GET	SOURCE	IEEE GET command triggering.
TRIG ON X	SOURCE	IEEE X command triggering.
NOT SETTLED	—	Additional trigger received before programmed settling time expired (trigger is processed).

3.4.3 IEEE-488 Status Indicators

The TALK, LISTEN, and REMOTE LEDs (shown in Figure 3-3) indicate these modes when the Model 707 is being programmed over the IEEE-488 bus. The TALK and LISTEN indicators show when the unit has been addressed to talk or listen. These talk and listen commands are derived from the unit's primary address. REMOTE turns on to show when the unit is placed in remote by addressing it to listen with the REN line true. (All front panel controls except LOCAL and POWER are inoperative when REMOTE is on.) Local operation is restored by pressing LOCAL unless the IEEE-488 LLO (Local Lockout) command is in effect. See Section 4 for details of IEEE-488 bus operation.

3.4.4 Crosspoint Display LEDs

As shown in Figure 3-4, the crosspoint display has six blocks of LEDs (one per card slot). Each block has 8 rows (A-H) by 12 columns (1-12, 13-24, etc.) of LEDs. The display LEDs can show the current open/closed relay states, the on/off states of a setup from in memory, or the on/off states of a setup currently being edited. The on/off states of crosspoint LEDs can be changed by front panel keys, commands over the bus, or an optional light pen. Modified displays can be stored in memory or sent to the relays.

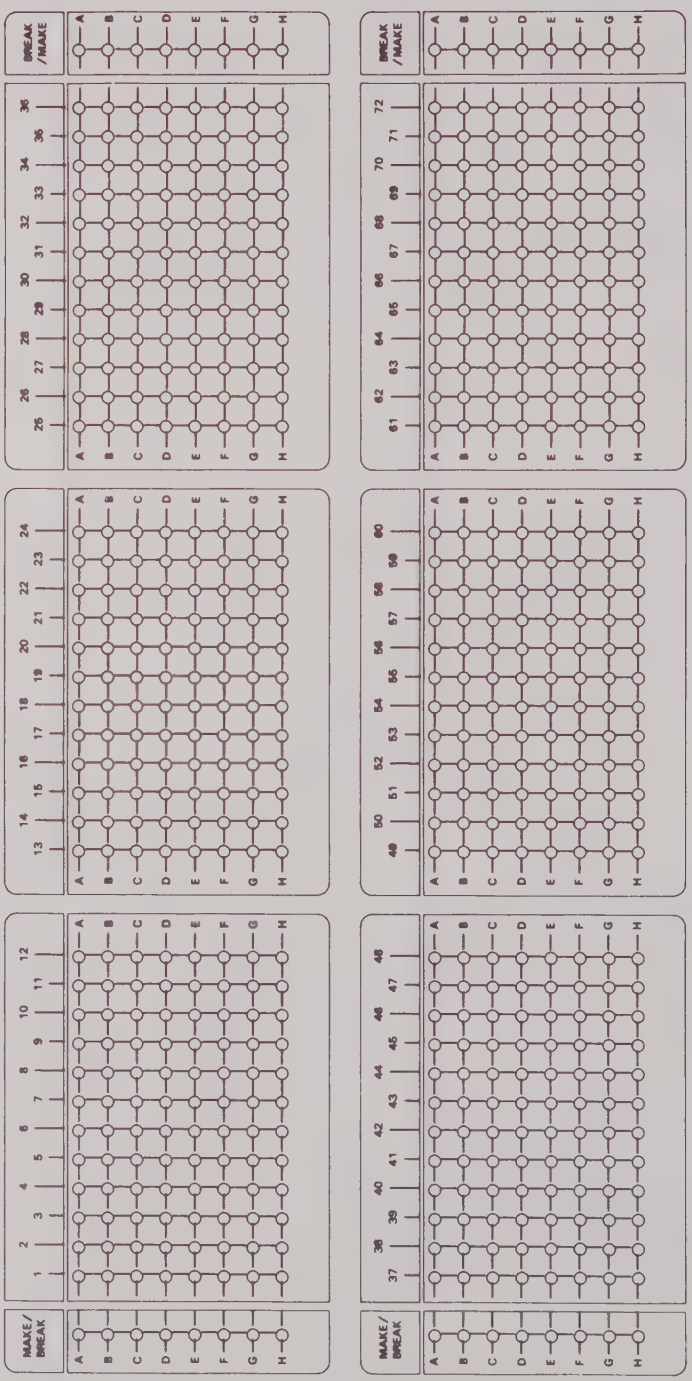


Figure 3-4. Crosspoint Display

3.4.5 Make/Break and Break/Make LEDs

The MAKE/BREAK and BREAK/MAKE displays each have two blocks of LEDs labeled A-H (one for columns 1-36, the other for columns 37-72). Refer to Figure 3-4. Each block shows which rows have been selected for make/break or break/make operation. When switching current sources, use make/break operation to keep current flowing and eliminate switching transients. When switching voltage sources, use break/make operation to avoid momentary shorting of two paths together.

The LEDs can be turned on or off by pressing a row letter key and the MAKE/BREAK or BREAK/MAKE key, or with an optional light pen. Note that selecting a row for break/make de-selects it for make/break and vice versa.

3.4.6 Light Pen

The light pen is an optional input device for toggling the on/off states of crosspoint display LEDs, MAKE/BREAK row LEDs, and BREAK/MAKE row LEDs. One light pen is used to control the LEDs of all units in a master/slave system.

As seen in Figure 3-5, the light pen plugs into the front panel of stand-alone or master units. (Remove the light pen by pressing the button on the connector plug while pulling out the plug.) Mount the light pen holder on the left handle of the Model 707 by tightening the allen-head screw shown in Figure 3-5.

To toggle the state of a crosspoint LED or MAKE/BREAK, BREAK/MAKE LED with the light pen, follow these steps:

1. Hold the light pen as you would an ordinary pen.
2. With the light pen perpendicular to the front panel overlay at the desired LED, press the button on the pen's barrel.
3. Proper usage will toggle the state of the LED. If the button is pressed while not on an LED, the message LIGHT PEN???? is displayed briefly, then the Model 707 reverts to its previous display.

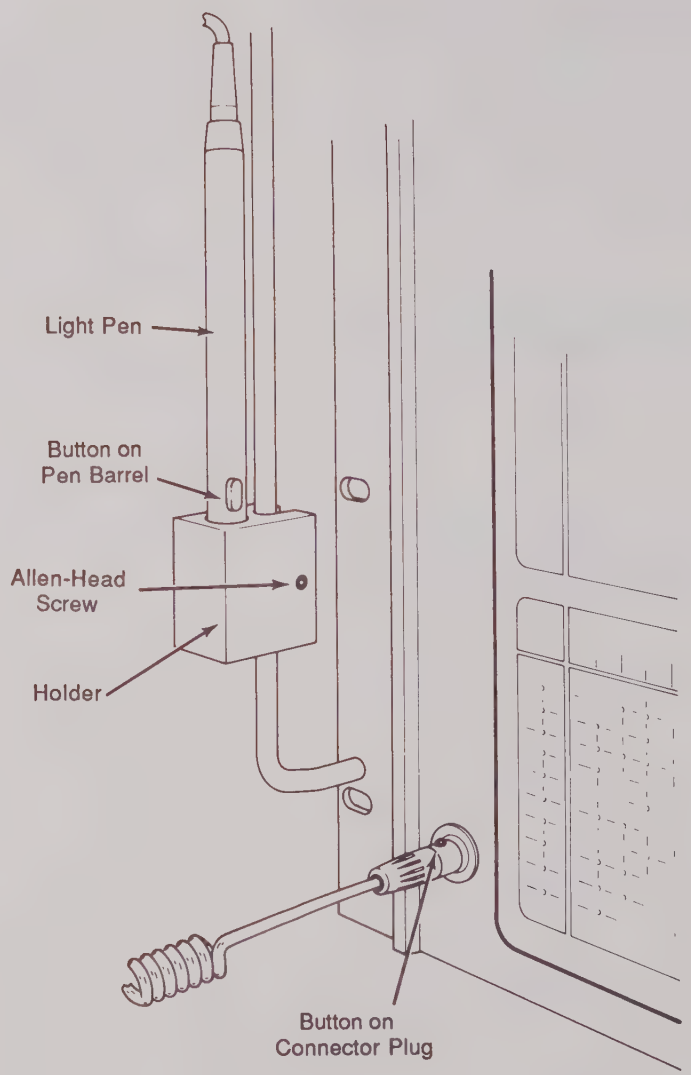


Figure 3-5. Light Pen

3.5 SELECTING CROSSPOINT DISPLAY

In the CROSSPOINT DISPLAY key group on the front panel are two keys that are used to bring setups to the crosspoint display. See Figure 3-6. Three LEDs in the group indicate the source of setup data. Only one of these LEDs is lit at a time:

- MEMORY LED—When lit, the crosspoint display shows a setup stored in memory.
- RELAYS LED—When lit, the crosspoint display shows the current relay setup.
- CROSSPOINT DISPLAY MODIFIED LED—When lit, the crosspoint display shows a modified setup that was previously from memory or from the relays.

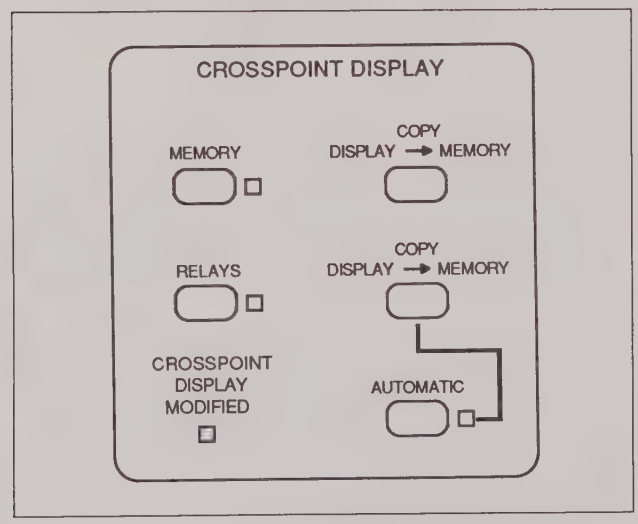


Figure 3-6. Crosspoint Display Keys

Pressing the MEMORY key displays a stored relay setup (location shown in MEMORY STEP field) on the crosspoint display and lights the MEMORY indicator. If a valid location (1-100) is entered first from the data entry keypad, that setup is displayed on the crosspoints and in the MEMORY STEP field. (The INVALID INPUT message is displayed briefly for locations out of range.) The CANCEL key can be used to remove incorrect entries from the alphanumeric display.

When the MEMORY indicator is lit, a setup can also be displayed by entering a valid location and pressing ENTER, or by pressing a SCROLL key to display the setup at MEMORY STEP ±1. If you press and hold a SCROLL key, the MEMORY STEP field is updated continuously. As location 000 is invalid for MEMORY STEP, the SCROLL keys skip this location when incrementing or decrementing.

If the displayed setup is modified by IEEE-488 commands, the crosspoint display changes if the MEMORY indicator is lit. In other words, if you are editing a setup, changes to its source do not appear.

Pressing the RELAYS key displays the current relay setup on the crosspoint display and lights the RELAYS indicator. If a valid location (0-100) is entered first, that setup is sent to the relays and displayed on the crosspoints and in the RELAY STEP field. When location 000 is selected in this manner, the relay states do not change.

When the RELAYS indicator is lit, a setup can also be sent to the relays and displayed by entering a valid location and pressing ENTER, or by pressing a SCROLL key to send and display the setup at RELAY STEP ±1. If you press and hold a SCROLL key, the RELAY STEP field is updated continuously. As the SCROLL keys increment and decrement the RELAY STEP field through location 000, there is no effect on the relays. That is, when the RELAY STEP is decremented from 001 to 000, or when incremented from 100 to 000, the relays do not change state.

If the relays change due to a trigger or IEEE-488 commands, the crosspoint display changes only if the RELAYS indicator is lit.

3.6 MODIFYING CROSSPOINT DISPLAY

After choosing the source of the setup, a crosspoint display can be modified by turning on/off crosspoint LEDs with front panel keys or the light pen. As discussed in the next paragraph, if the AUTOMATIC (COPY DISPLAY→ RELAYS) indicator is lit, these actions open/close relays immediately.

The alphabetic data entry keys (A-H) are for entering the row part of a crosspoint address. The numeric keys (0-9) are for entering column numbers. Use the CANCEL key to remove incorrect entries from the alphanumeric display. Refer to Figure 3-7.

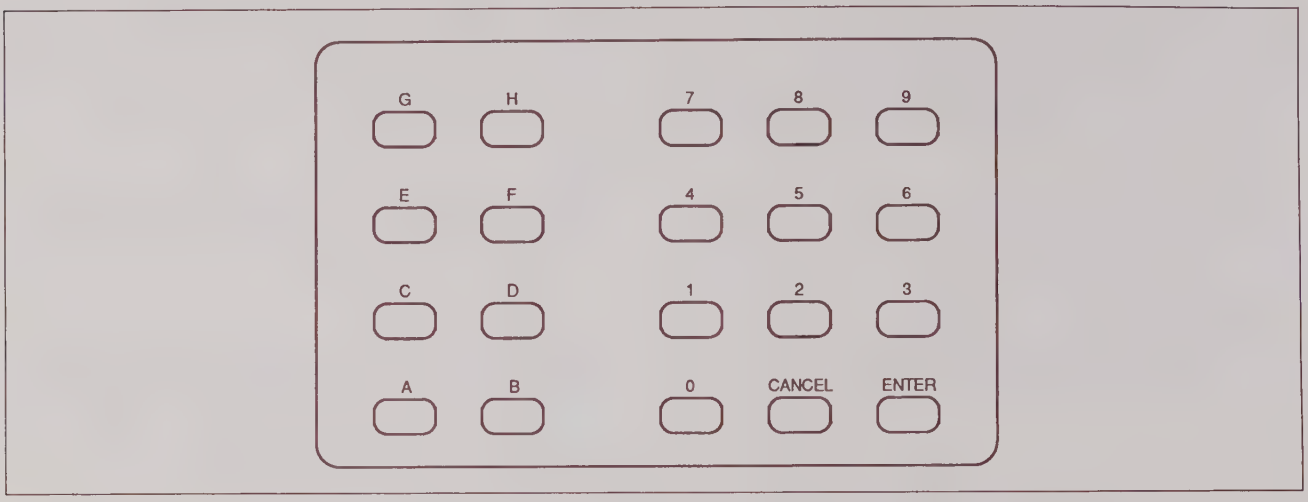


Figure 3-7. Data Entry Keys

The maximum valid column number with a single unit is 72. If several mainframes are connected and programmed for master/slave operation, the maximum column can be up to 360 (with five units).

When a valid crosspoint address (row and column) is in the alphanumeric display, pressing the OPEN key turns off the crosspoint display LED. (The message INVALID INPUT is displayed for addresses out of range.) If the AUTOMATIC (COPY DISPLAY→RELAYS) indicator is lit, the corresponding relay opens immediately. The CLOSE key performs the same action as the OPEN key except that it turns on crosspoint display LEDs and relays.

Pressing the CLEAR key turns off all crosspoint display LEDs. If the AUTOMATIC (COPY DISPLAY→RELAYS) indicator is lit, all relays are opened immediately.

The CROSSPOINT DISPLAY MODIFIED indicator lights and the MEMORY or RELAYS indicator go out when changes are made to the crosspoint display, making it different from the configuration of its source. It also lights when opening an already open crosspoint and closing an already closed crosspoint. The SCROLL keys are not active when the CROSSPOINT DISPLAY MODIFIED indicator is lit.

The optional light pen can also be used to turn on and off crosspoint LEDs. Just hold it perpendicular to the front panel overlay at the desired LED and press the button on its barrel. This action toggles the state of the LED.

The maximum number of simultaneously closed crosspoints depends on the specified drive current per crosspoint of each card. The total relay drive current required per mainframe cannot exceed 4.5A, since the 6V/6A power supply also provides 1.5A for the front panel display.

Table 3-5 lists the maximum crosspoint closures for each card. Since the Model 7072 has three different types of relays, its drive current is row specific. If relays from other cards (or other Model 7072 rows) in the same unit are energized at the same time, their drive currents will reduce this quantity.

Table 3-5. Maximum Number of Closed Crosspoints

Card	Rows	Relay Drive Current (per crosspoint)	Maximum Closed Crosspoints (per mainframe)
7071	A-H	15mA	300
7072	A-B	40mA	112
	C-F	60mA	75
	G-H	80mA	56
7073	A-H	20mA	225

3.7 COPYING CROSSPOINT DISPLAY

The setup data displayed on the crosspoint LEDs can be stored in non-volatile memory of the Model 707 or can be

sent directly to the relays by pressing either the COPY DISPLAY→MEMORY or the COPY DISPLAY→RELAYS key, seen previously in Figure 3-6.

With the COPY DISPLAY→MEMORY key, the displayed crosspoint configuration is stored at the setup location shown in MEMORY STEP field. It overwrites the present setup data at that location. If a valid location is keyed in first, pressing this key stores the crosspoint configuration at that setup and sets the MEMORY STEP field to that location. If the CROSSPOINT DISPLAY MODIFIED indicator is lit, it goes out and the MEMORY LED lights. The INVALID INPUT message is displayed briefly if you try to copy to a setup location below one or above 100.

In master/slave configurations, each unit stores its own portion of each stored setup.

When the COPY DISPLAY→RELAYS key is pressed, the displayed crosspoint configuration is sent to the relays:

- If the MEMORY indicator is lit (i.e., the crosspoint display shows an unmodified setup from memory), the RELAY STEP field is set to the MEMORY STEP field. In effect, this copies a setup from memory to the relays.
- If the RELAYS indicator is lit, the RELAY STEP field is not affected, as it reflects the last stored setup sent to the relays.
- If CROSSPOINT DISPLAY MODIFIED is lit, it goes out and the RELAYS LED lights.

Copying the crosspoint display to the relays can be performed automatically with the toggle-action AUTOMATIC (COPY DISPLAY→RELAYS) key. When the AUTOMATIC indicator is lit, any change to the crosspoint display is also sent to the relays at the same time. This action is apparent when scrolling through unmodified stored setups, as the MEMORY STEP and RELAY STEP fields will sequence together. Changes to the crosspoint display while the AUTOMATIC LED and RELAY LEDs are lit, cause the CROSSPOINT DISPLAY MODIFIED LED to blink and the RELAYS LED to remain lit.

3.8 INSERTING AND DELETING STORED SETUPS

The two keys in the MEMORY group (see Figure 3-8) operate on setups stored in Model 707 memory. These keys are active only when the MEMORY LED is lit.

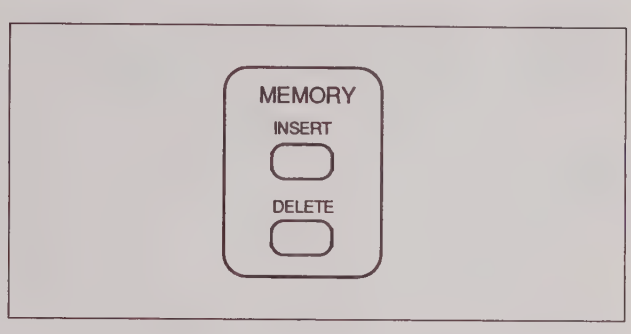


Figure 3-8. Memory Keys

Use the INSERT key to place a blank setup at the memory location shown in the MEMORY STEP field. While the insert is taking place, the alphanumeric display is blank. All setups from the selected setup through 99 are moved up one location. (Setup 100 is deleted by overwriting it with setup 99.) After the insert operation, the crosspoint LEDs display a blank setup.

If a valid location is keyed in first, the MEMORY STEP field is set there and then the insert operation takes place.

Pressing the DELETE key removes the stored setup at the location shown in the MEMORY STEP field. While the delete is taking place, the alphanumeric display is blank. All setups higher than the selected setup are moved down one location. (Setup 100 is cleared.) After the delete operation, the crosspoint LEDs display the new setup "nnn", which previously was setup "nnn+1".

If a valid location is keyed in first, the MEMORY STEP field is set there and then the deletion takes place.

In master/slave configurations, the insert blank setup and delete stored setup operations perform similarly, except on all units of the system.

3.9 MENU OPERATIONS

The Model 707 has several operations that are performed by front panel menu items. Select the first item by pressing the MENU key, subsequent presses of MENU display the remaining items (see Table 3-6). To view all current menu selections, just press and hold the MENU key.

Status items are displayed with no user action. Numeric items are modified by keying in the desired value with the data entry keys and pressing ENTER. Multiple choice items are selected by scrolling through the choices until the desired one is displayed, then pressing ENTER. Immediate action items are invoked by pressing ENTER.

If no modifications are made with the SCROLL or data entry keys, pressing CANCEL exits from the menu without changing any values; otherwise CANCEL restores the current value of the parameter. Pressing ENTER exits from the menu (with changes), except when programming the digital output status.

Table 3-6. Menu Operations

Message	Item Description	Type
IN iii OUT ooo	View digital input, program digital output.	status/numeric
EXT TRIG FALL EXT TRIG RISE	Select which edge of external trigger pulse triggers Model 707 (falling or rising).	multiple choice
MATRIX RDY LO MATRIX RDY HI	Select matrix ready output level (active LO or HI).	multiple choice
STANDALONE MASTER	Select stand-alone or master/slave operation.	multiple choice
IEEE-488 nn	Program IEEE-488 bus address.	numeric
HWSETL nnn mS	View longest relay (hardware) settling time of cards in system.	status
n cccc	View slot number (n) and card label (cccc).	status
SELF TEST	Execute self test.	immediate action
FACTORY INIT	Return to factory defaults. (All stored setups are cleared.)	immediate action

3.9.1 Digital I/O

The TTL-compatible DIGITAL I/O port has eight data lines for inputs, eight data lines for outputs, and two control lines for handshaking. The pinout for the rear panel DB-25 connector is shown in Figure 3-9. Status of the input lines is viewed and states of the output lines are programmed through the first menu item. With no input connections and power-up default conditions for the output, the alphanumeric display will read the following decimal values:

IN 255 OUT 000

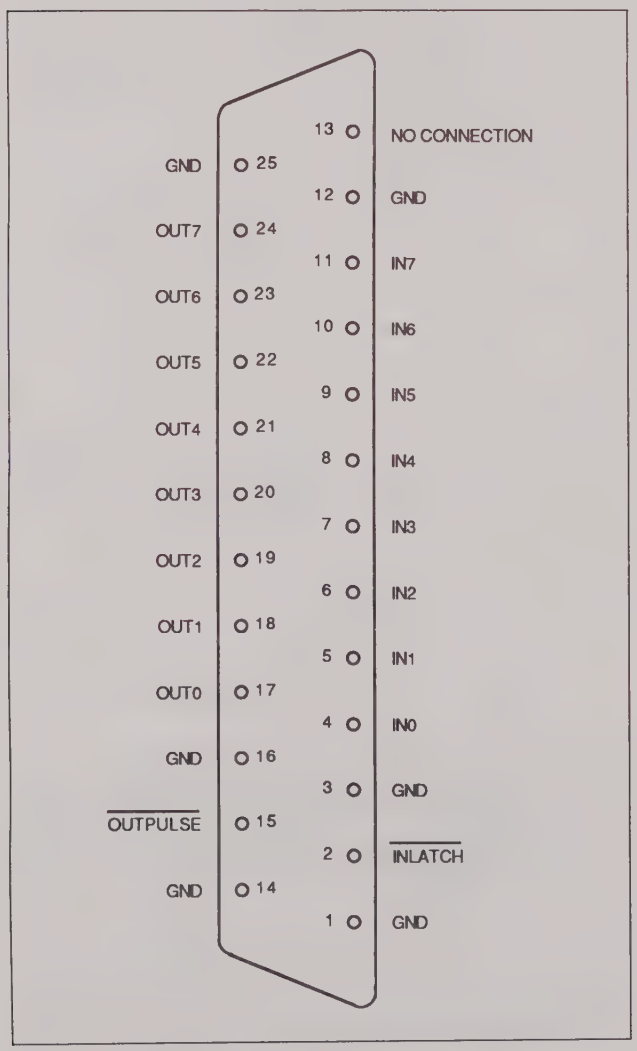


Figure 3-9. Digital I/O Port

The digital inputs are logic high with no connections. Use the control line INLATCH (low true) to latch in the digital inputs when changing an input state.

To program the digital output states, select the desired decimal value with the data entry keys and press ENTER. You can now key in another value and press ENTER, or press CANCEL to exit menu mode, or press MENU to continue to the next item. Each time the digital outputs are programmed, even if the states are not changed, the control line OUTPULSE is brought low.

With master/slave configurations, only the DIGITAL I/O port of the master unit is available for viewing and programming.

3.9.2 External Trigger

If triggers are enabled, and external trigger is selected as a source, a TTL-compatible pulse of at least 600nsec duration at the rear panel EXTERNAL TRIGGER INPUT jack triggers the Model 707. The input BNC jack is shown in Figure 3-10.

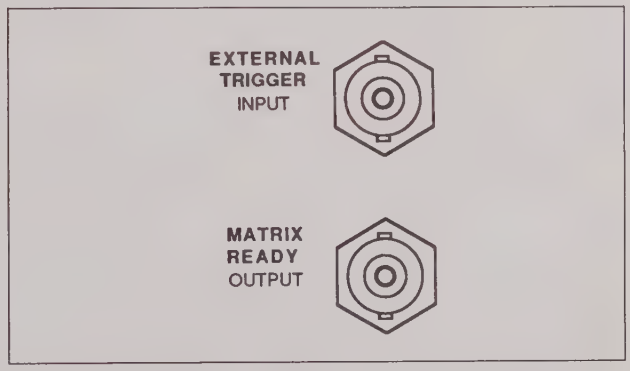


Figure 3-10. Rear Panel BNC Jacks

The unit can be programmed with a menu item for which edge (falling or rising) of the external trigger pulse causes a transfer of stored setup data to the relays. Sample trigger pulses are shown in Figure 3-11. To select which pulse edge triggers, use the MENU key to choose the menu item for external trigger. The power-up default display will read:

EXT TRIG FALL

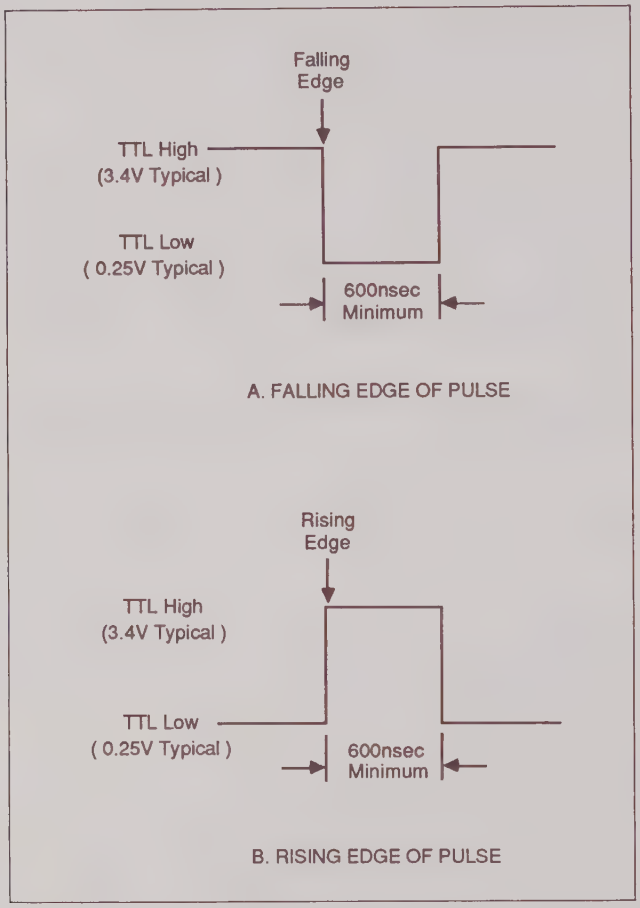


Figure 3-11. Sample External Trigger Pulses

To choose the alternate external trigger state, use the SCROLL ▲ or ▼ keys, then press ENTER. This action also exits from the menu mode. (Pressing CANCEL instead of ENTER returns external trigger to its previous state and the Model 707 remains in menu mode.)

In master/slave configurations, only the EXTERNAL TRIGGER INPUT port of the master unit is active.

See paragraph 3.11 for more information on triggering the Model 707.

3.9.3 Matrix Ready

The Model 707 provides a TTL-compatible signal at its rear panel MATRIX READY OUTPUT jack. The output BNC jack was shown in Figure 3-10. The MATRIX READY signal goes false when relays are switched and goes true at the end of the programmed settling time. (As described in paragraph 3.11, this is also after the relay settling time.)

Through a menu item, the unit can be programmed for a high- or low-true MATRIX READY signal, as seen in Figure 3-12. To select the active state of the signal, press the MENU key until the MATRIX RDY item is displayed. The power-up default display will read:

MATRIX RDY LO

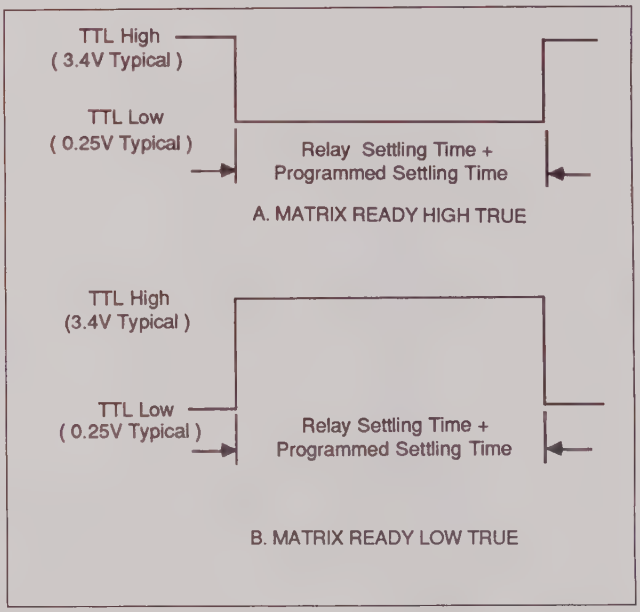


Figure 3-12. Sample Matrix Ready Pulses

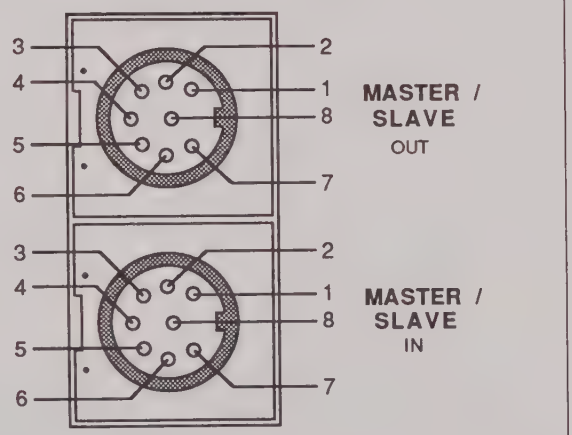
To choose the other active state, use the SCROLL ▲ or ▼ keys, then press ENTER. This action also exits from the menu mode. (Pressing CANCEL instead of ENTER returns matrix ready to its previous state and the Model 707 remains in menu mode.)

In master/slave configurations, the MATRIX READY signals of all units function, but only that of the master is to be considered accurate.

3.9.4 Stand-alone and Master/Slave

One method to expand system size is to connect up to five mainframes in a master/slave configuration, where all units are daisy-chained for serial communication and control. System operations are performed through the master unit, either over the IEEE-488 bus or the master's front panel (including the light pen). A master/slave system appears as a single unit (and IEEE-488 address) with a maximum size of 8 rows by 360 columns. Selection of stand-alone or master/slave operation is done with a menu item.

As previously described in paragraph 2.6, the MASTER/SLAVE OUT and MASTER/SLAVE IN rear panel connectors are used to connect DIN cables in a closed loop. The connector pinouts are defined in Figure 3-13.



Pin	Master/Slave IN	Master/Slave Out
1	M/S TRIGGER (low true)	M/S TRIGGER (low true)
2	ALLREADY	ALLREADY
3	LPRESET (low true)	LPRESET (low true)
4	LPSENSE (low true)	LPSENSE (low true)
5	RxDATA	TxDATA
6-8	Chassis Ground	Chassis Ground

Figure 3-13. Master/Slave Connectors

After interconnecting and powering up all units, one unit is selected to be a master.

This action is performed by pressing the MENU key of the desired master mainframe until the display reads STAND ALONE. Next, scroll up or down to the MASTER message. Then, press the ENTER key to initiate the master/slave loop. If the loop is complete (MASTER/SLAVE OUT to MASTER/SLAVE IN in a daisy chain among all units), the master unit will exit menu mode and the other units will display SLAVE 1, SLAVE 2, etc. (The slave number is determined by the unit's position in the loop.) If the loop of DIN cables is not closed, the master will display the message M/S ERROR and all units will remain as stand-alones.

When the units are powered up one at a time, they will display the message M/S LOOP DOWN until all units are powered.

CAUTION

When it is necessary to cycle power on a slave unit, turn off all units in the master/slave configuration. This procedure prevents the open communication and control loop from putting the slave unit in an undesirable state.

During master/slave operation, most front and rear panel controls of the slave units are inactive. Table 3-7 shows which controls and indicators remain active for slave units.

The master unit communicates with the slaves only when necessary; it does not continuously monitor the status of the closed-loop configuration. Hence, a disconnected master/slave loop cable is not detected, and the message M/S ERROR is not displayed, until the master attempts to send or receive data around the loop. The steps taken by a master unit to recover from an M/S ERROR are outlined below:

1. The master stops processing IEEE-488 bus commands, returns to stand-alone operation, and disables.
2. The slave units remain the same as before the error occurred.
3. To re-initialize the loop, ensure that master/slave cables are secure, and select master/slave operations from the mainframe that previously was master.

Table 3-7. Status of Slave Unit Controls

Control, Indicator or Connector	Status
POWER	active
CROSSPOINT DISPLAY Group:	
MEMORY key and LED	only LED active
RELAYS key and LED	only LED active
CROSSPOINT DISPLAY MODIFIED LED	active
COPY DISPLAY→MEMORY	inactive
COPY DISPLAY→RELAYS	inactive
AUTOMATIC key and LED	only LED active
SCROLL ▲ and SCROLL ▼	inactive
MEMORY Group:	
INSERT	inactive
DELETE	inactive
MENU key and LED	inactive
SWITCHING Group:	
SETTLING TIME	inactive
MAKE/BREAK	inactive
BREAK/MAKE	inactive
LOCAL	inactive
TRIGGER Group:	
ENABLE key and LED	only LED active
SOURCE	inactive
MANUAL	inactive
Data Entry (A-H, 0-9)	inactive
CANCEL, ENTER	inactive
RESET	inactive
CLEAR, OPEN, CLOSE	inactive
Alphanumeric Display	active (Note 1)
TALK, LISTEN, REMOTE LEDs	inactive
Crosspoint Display LEDs	active
MAKE/BREAK and BREAK/MAKE Row LEDs	active
LIGHT PEN	inactive
Rear Panel Connectors:	
MASTER/SLAVE IN	active
MASTER/SLAVE OUT	active
EXTERNAL TRIGGER INPUT	inactive
MATRIX READY OUTPUT	active (Note 2)
RELAY TEST	not used
DIGITAL I/O	inactive (Note 3)
IEEE-488 INTERFACE	not used

Notes:

1. Messages only.
2. Timing accuracy not guaranteed.
3. Outputs set to all low.

3.9.5 IEEE-488 Bus Address

The Model 707 communicates over the IEEE-488 bus through the rear panel connection shown in Figure 3-14. When connected to a bus controller, instrument operating modes can be programmed. Note that IEEE-488 common is always grounded. IEEE-488 interface function codes are marked adjacent to the connector.

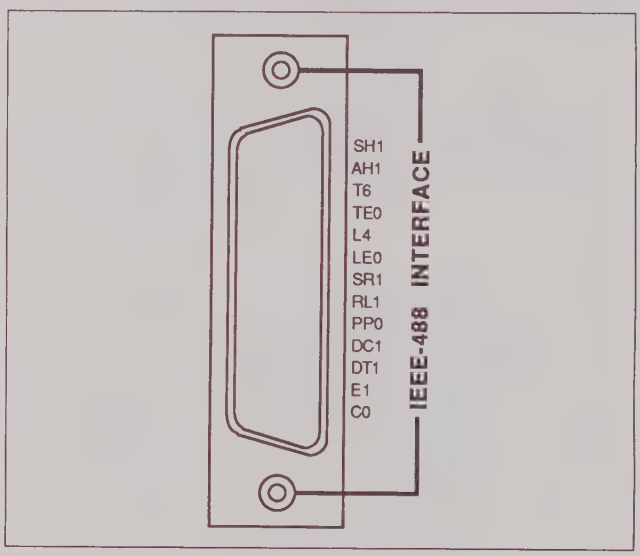


Figure 3-14. IEEE-488 Bus Connector

A menu item is used to set the primary address of the Model 707 for bus operation. The primary address of the Model 707 is factory set to 18, but it may be set to any value between 0 and 30 as long as address conflicts with other instruments or the bus controller are avoided.

To check the present primary address or to change to a new one, perform the following procedure:

1. Press the MENU key until the current primary address is displayed. For example, if the instrument is set to primary address 18, the following message is displayed:

   IEEE-488 18

2. Press CANCEL to retain the present address and exit menu mode.
3. To change the primary address, use the data entry keys to key in a new value, then press ENTER. This action will also exit menu mode. The new address will be stored in memory so that the instrument powers up to that address.

NOTE

Each device on the bus must have a unique primary address. Failure to observe this precaution will probably result in erratic bus operation.

Section 4 contains detailed information on operating the Model 707 over the IEEE-488.

3.9.6 Relay (Hardware) Settling Times

The card specification "relay settling time" is the time needed for the relays to actuate or release (including contact bounce time) and pass a clean signal. Since this specification is card dependent, the Model 707 must identify on power-up which cards are installed to determine the longest relay settling time in the system (stand-alone or master/slave). This value is not user-modified, but the total settling time for a switching operation can be lengthened by using the programmed settling time, as explained in paragraph 3.10.

To view the relay (hardware) settling time of the system, press the MENU key until the display reads:

HWSETL 015 mS

In this example, there is a Model 7072 or 7073 matrix card present in the system. Press CANCEL to exit the menu mode.

See paragraph 3.11 for a discussion of settling times and triggers.

3.9.7 Card Labels

Each matrix card can be identified by the Model 707. You can view the card labels of the present configuration by using a menu item. Press the MENU key until the alphanumeric display reads:

1 7072

In this case, a Model 7072 is in slot #1. Use the SCROLL ▲ to view the card label of the next slot. If no card is present, the display will be:

2 NONE

Continue pressing the SCROLL ▲ or ▼ keys for the remaining slots or press CANCEL to exit the menu mode.

In master/slave configurations, all units display card labels simultaneously.

3.9.8 Self-test

The self-test program is intended to check ROM, RAM, and the front panel LED indicators. This test is also part of the power-up sequence. If you want to run the test without cycling power, use the following procedure to select and run it:

1. Press the menu key until the display reads SELF TEST.
2. Press the ENTER key to initiate the test. The unit's ROM and RAM are checked. Next, all the front panel LEDs are lit for your inspection. If no errors are detected, menu mode is exited.

If there is an error in ROM or RAM, a ROM FAIL or RAM FAIL message is displayed until a key press or bus operation. See Section 6 for troubleshooting procedures.

For master/slave configurations, all units are tested simultaneously, so you might have to run the test more than once to inspect all LED indicators.

3.9.9 Factory Defaults

A menu item can be used to return the Model 707 to the factory default conditions previously listed in Table 3-2. To initiate this action, follow these steps:

1. Press the MENU key until the display shows FACTORY INIT.
2. Press the ENTER key. The display will read ENTER IF SURE. (This additional keypress is to prevent unintentional initialization.) At this step you can press CANCEL to exit menu mode, or you can continue with the next step.
3. Press the ENTER key again. The Model 707 will return to factory settings and exit menu mode.

In master/slave configurations, all units return to factory defaults when this menu item is selected from the master unit.

3.10 SELECTING SWITCHING PARAMETERS

The Model 707 has three switching parameters that are user-modified: the programmed settling time, make-before-break rows, and break-before-make rows. These values of these parameters are in effect for all relay switching until they are changed. Figure 3-15 shows the front panel keys of the switching group.

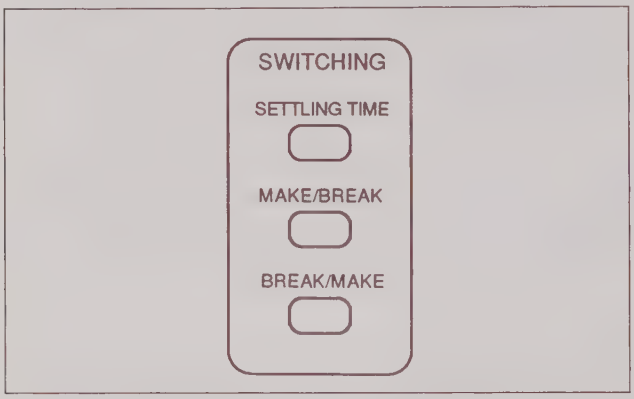


Figure 3-15. Switching Keys

3.10.1 Programmed Settling Time

The programmed settling time is a variable switching delay that can be used to lengthen the fixed delay of the relay (hardware) settling time. You can select, in 1msec increments, up to 65 seconds of an additional switching delay.

If an additional trigger is received during this time, it is processed and the message NOT SETTLED is displayed. At the end of the programmed settling time, the Model 707 sets the MATRIX READY output true.

To view or change the programed settling time, press the SETTLING TIME key in the SWITCHING key group. The value of the programmed settling time value is displayed as:

SETL 00000 mS

To exit the display without changing the value, just press CANCEL. To change the value, enter between 0-65000 with the data entry keys and press ENTER. This action also returns the display to the RELAY STEP and MEMORY STEP.

The programmed settling time is in effect for all crosspoint relay open/close operations until it is reprogrammed. Its effect on trigger response times is described in paragraph 3.11.

3.10.2 Make/Break and Break/Make Rows

Make-before-break switching of relays is defined as connecting a new circuit before disconnecting the present circuit. It is used to eliminate transients caused by switching between current sources. Break-before-make switching means to disconnect the present circuit before connecting a new circuit. It is used to avoid momentary shorting of two voltage sources. Both of these switching operations are supported by the Model 707.

Rows of crosspoint relays are user-selectable for make/break (make-before-break), break/make (break-before-make), or "don't care" operation. The selections will be in effect for all switching until new choices are made. When make/break or break/make operation is chosen, the Model 707 automatically switches the crosspoint relays through intermediate setups to perform the following steps:

1. Crosspoints in break/make rows are opened.
2. Crosspoints in make/break rows are closed.
3. Crosspoints in make/break rows are opened.
4. Crosspoints in break/make rows are closed; crosspoints in "don't care" rows are opened or closed accordingly.

These steps are transparent to the user except for the increased settling time. If either make/break or break/make rows are not selected, the appropriate steps in the previous list are deleted and the total settling time decreases. As make/break and break/make operations affect settling times and trigger response, these operations are further discussed in paragraph 3.11.

The front panel MAKE/BREAK and BREAK/MAKE keys are used in conjunction with the data entry keys to select rows for operation as make/break or break/make. When a row designation (A-H) is selected and displayed by itself, the MAKE/BREAK and BREAK/MAKE keys toggle the state of the MAKE/BREAK or BREAK/MAKE LED for that row and immediately reprograms the Model 707 for the new operation. The INVALID INPUT message is displayed briefly if you press the MAKE/BREAK or BREAK/MAKE key without first selecting a row or if a row/column address is displayed instead of just a row.

Note that selecting a row for make/break de-selects it for break/make and vice versa. The various front panel operations are listed in Table 3-8.

Table 3-8. Make/Break and Break/Make Front Panel Operation

Present State	Action	Next State
Don't Care	Select Make/Break Select Break/Make	Make/Break Break/Make
Make/Break	Select Break/Make De-select Make/Break	Break/Make Don't Care
Break/Make	Select Make/Break De-select Break/Make	Make/Break Don't Care

The optional light pen can be used to toggle the LED states directly. The light pen can also select rows for make/break or break/make operation from slave units. The row selection is in effect for all units connected in a master/slave configuration.

3.11 TRIGGERING

When a Model 707 stand-alone or master unit is triggered, the stored relay setup from RELAY STEP+1 is sent to the relays. Triggers are enabled with the front panel ENABLE key of the TRIGGER group (see Figure 3-16). This key toggles between triggers enabled and triggers disabled. When triggers are enabled, the ENABLE LED is lit.

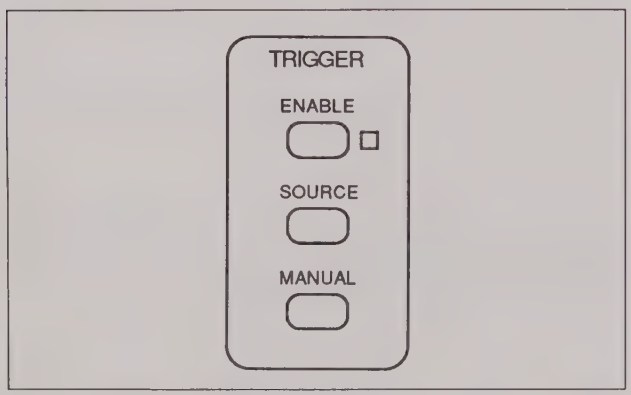


Figure 3-16. Trigger Keys

The maximum trigger rate is specified with no make/break or break/make rows selected. As will be described in paragraph 3.11.3, additional switching delays are necessary with make/break or break/make operation.

3.11.1 Trigger Sources

The programmed trigger source provides the stimulus to increment to the next stored setup. Trigger sources include:

- Front panel MANUAL key—When triggers are enabled, this key is always operational (on stand-alone and master units) regardless of the selected source (unless the unit is placed in remote over the IEEE-488 bus).
- External trigger pulse—An appropriate pulse, applied to the EXTERNAL TRIGGER INPUT jack on the rear panel, provides the trigger stimulus.
- IEEE command triggers—IEEE-488 GET, X, or talk commands provide the stimulus when the appropriate source is selected.

Select the trigger source as follows:

1. Press SOURCE and note that the current trigger source is displayed:

   TRIG ON EXT

   This is the display for external triggering (the power-up default). Table 3-9 lists the displays for all trigger sources.
2. Press the SCROLL ▲ or ▼ keys until the desired trigger source is displayed. Then press ENTER to select it and exit menu mode.
3. If another source is scrolled to before pressing ENTER, pressing CANCEL once returns the old selection, pressing it again exits menu mode.

Table 3-9. Front Panel Messages for Trigger Sources

Message	Description
TRIG ON TALK	IEEE talk command
TRIG ON GET	IEEE GET command
TRIG ON X	IEEE X command
TRIG ON EXT	External trigger pulse
TRIG ON KEY	Front panel MANUAL key only*

*If triggers are enabled, pressing MANUAL emulates the selected trigger source.

3.11.2 Front Panel Triggering

To trigger the Model 707 from the front panel, simply press the MANUAL key. (Press and hold for auto-repeat.) If trig-

gers are enabled, this key is always operational regardless of the selected trigger source (unless the unit is placed in remote over the IEEE-488 bus, in which case all front panel keys except LOCAL are locked out). Thus, front panel trigger source selection (TRIG ON KEY) provides a means to lock out all other trigger sources when only front panel triggering is desired.

Triggering will stop when the RELAY STEP field increments to 100. If you press MANUAL and the unit is not ready, an error message will be displayed, as discussed in the following paragraph.

3.11.3 Trigger Overrun Conditions

Once the instrument is triggered, it begins transferring relay setup data from mainframe memory to the matrix cards. If a second trigger is received while the unit is still transferring data, a trigger overrun condition will occur. In this case, the second trigger is not processed and the unit will display the following error message:

TRIG OVERRUN

After the time required for transferring relay data has elapsed, the Model 707 is able to process another trigger. If a trigger is received before the programmed settling time has elapsed, the following message is displayed:

NOT SETTLED

Figure 3-17 shows an example setup change and a timing diagram of the READY (for trigger) pulse and a high true MATRIX READY pulse when the Model 707 is processing the trigger. (The status of these signals is available in the serial poll byte, see Section 4.) This timing is for setups with no make/break or break/make rows.

When either make/break or break/make operation is selected, but not both, the Model 707 switches through an intermediate setup to ensure proper relay operation. If only make/break rows are selected, the Model 707 takes these steps:

1. Closes crosspoints in make/break rows yielding an intermediate setup.
2. Opens crosspoints in make/break rows and opens/closes crosspoints in "don't care" rows yielding the desired setup.

If only break/make rows are selected, the Model 707 takes these steps:

1. Opens crosspoints in break/make rows yielding an intermediate setup.
2. Closes crosspoints in break/make rows and opens/closes crosspoints in "don't care" rows yielding the desired setup.

An example of these operations is shown in Figure 3-18 with its corresponding timing diagram. By comparing Figures 3-17 and 3-18, you can see that the intermediate setup needed for make/break or break/make causes a delay in the assertion of READY and MATRIX READY equal to the relay settling time.

When a combination of make/break and break/make rows are selected, the Model 707 must switch through three intermediate setups to ensure proper relay operation. The steps taken by the unit are as follows:

1. Opens crosspoints in break/make rows yielding the first intermediate setup.
2. Closes crosspoints in make/break rows yielding the second intermediate setup.
3. Opens crosspoints in make/break rows yielding the third intermediate setup.
4. Closes crosspoints in break/make rows and opens/closes crosspoints in "don't care" rows yielding the desired setup.

Figure 3-19 shows an example setup change with the necessary intermediate setups. As the timing diagram shows, three additional relay settling time intervals are needed for the intermediate setups.

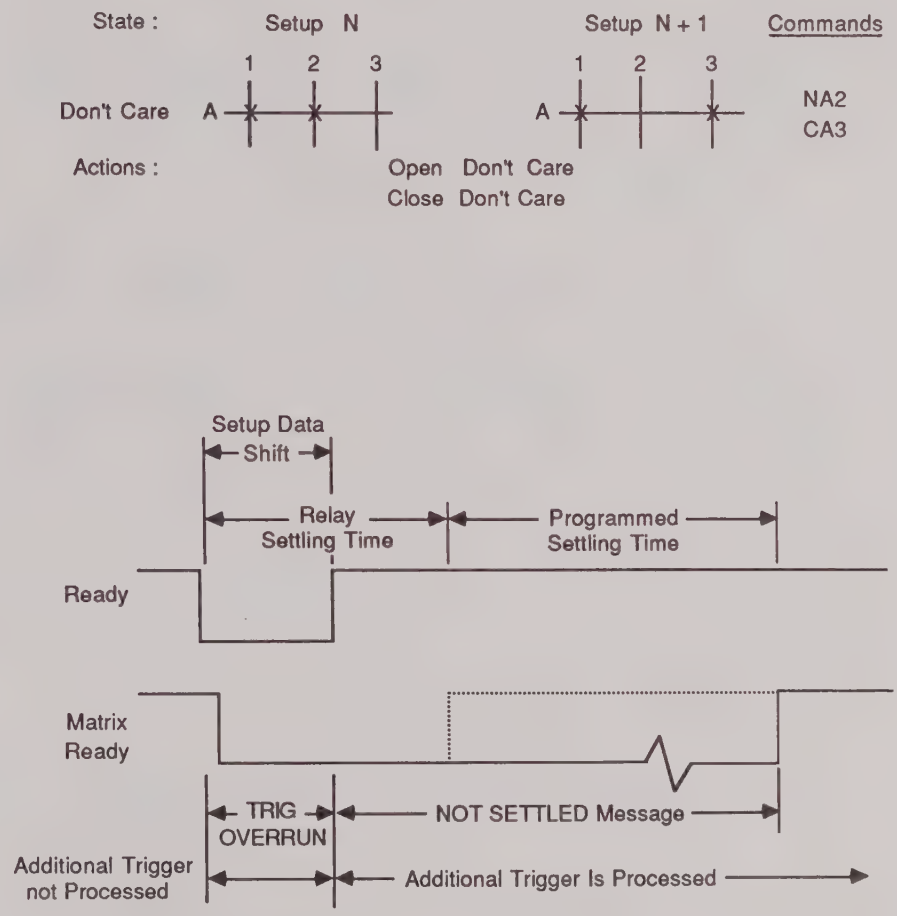


Figure 3-17. Timing without Make/Break or Break/Make Rows

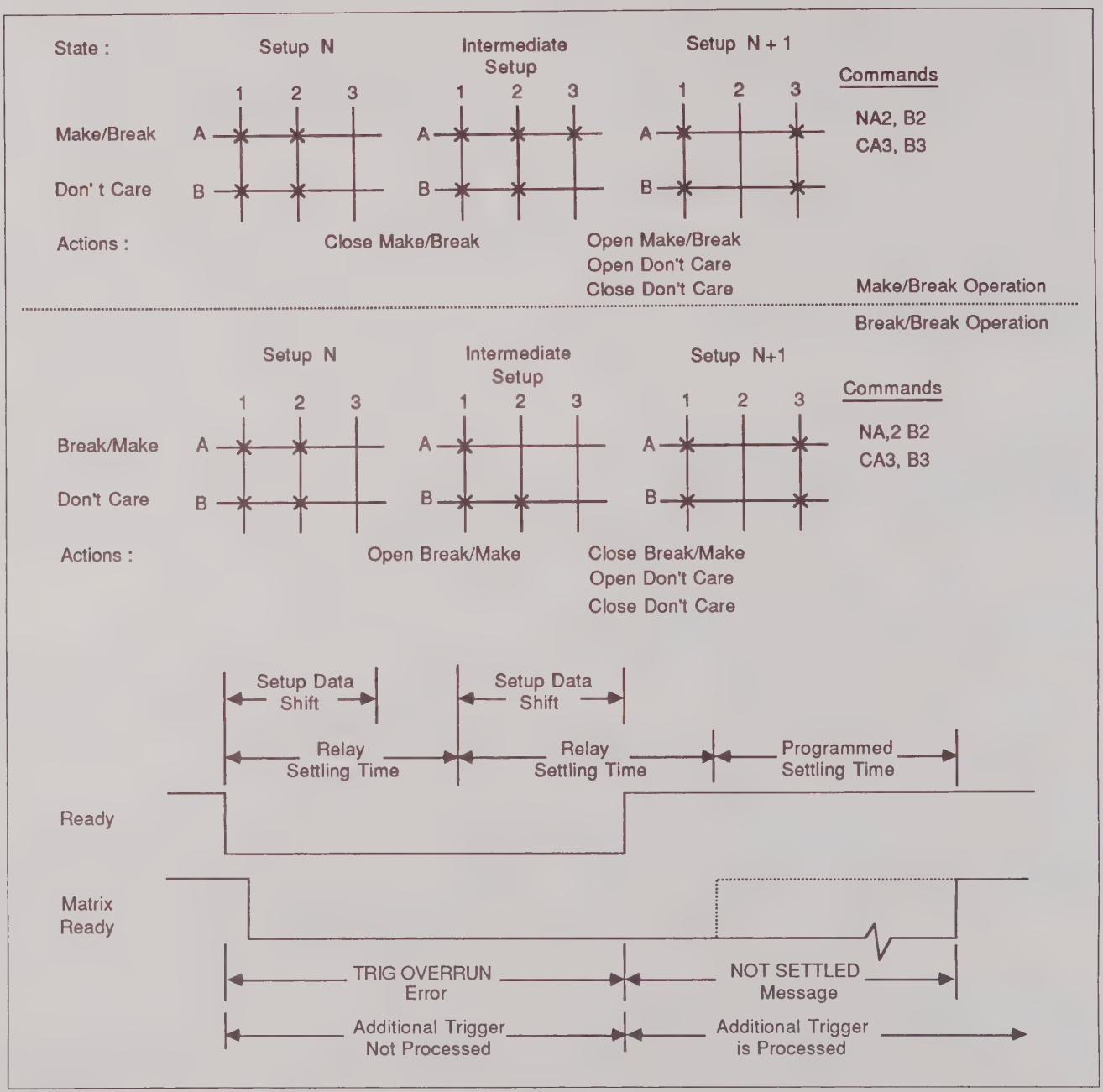


Figure 3-18. Timing with Either Make/Break or Break/Make Rows

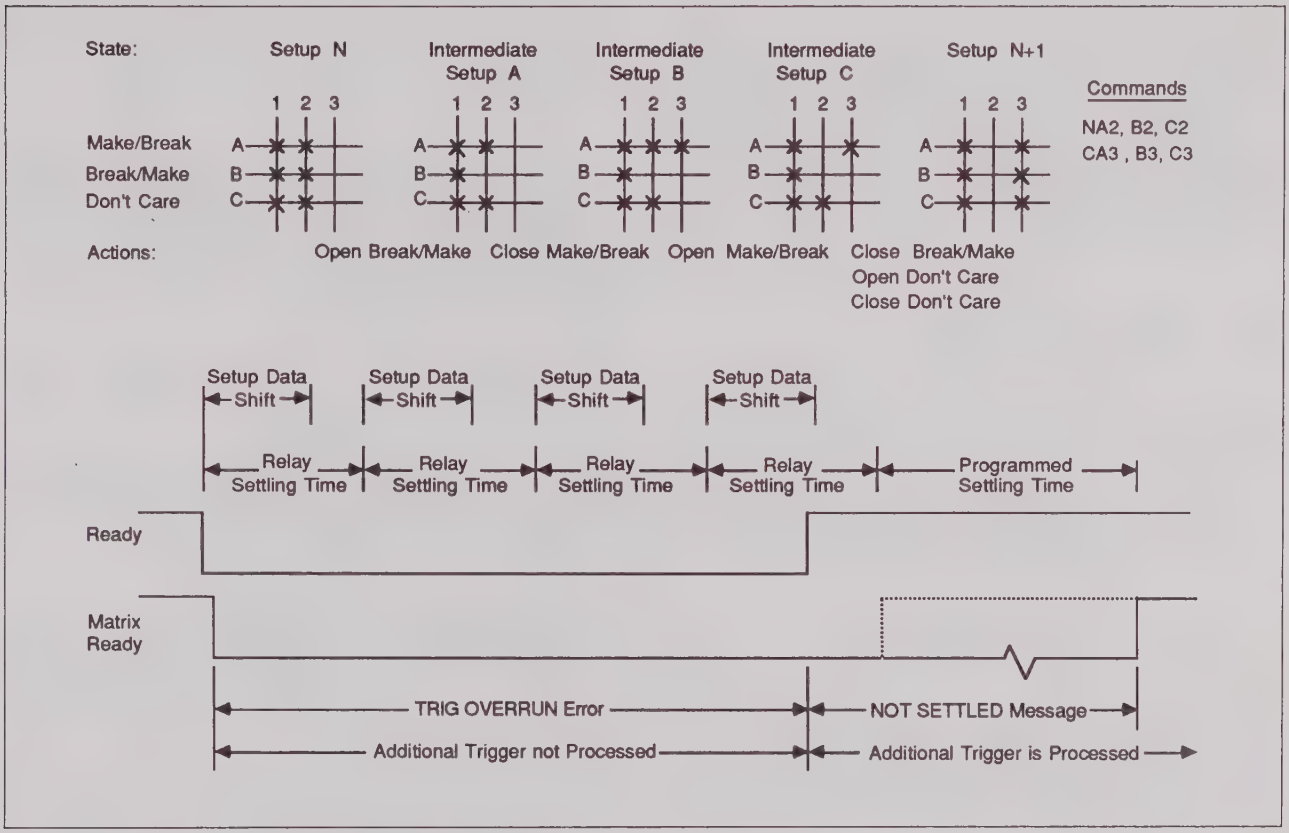


Figure 3-19. Timing with Both Make/Break and Break/Make Rows

3.11.4 External Trigger Input

To use external triggering, first select that source with the MENU and SCROLL keys as described in paragraph 3.11.1. With triggers enabled, the unit will then be triggered when an input pulse with the specifications previously shown in Figure 3-11 is applied to the EXTERNAL TRIGGER INPUT jack. The unit is triggered on either the falling (leading) or rising (trailing) edge of the pulse, as selected by a menu item.

3.11.5 Matrix Ready Output

The matrix ready output provides a TTL-compatible signal, as shown previously in Figure 3-12. This signal can be used to inform other instruments when the total settling time is complete. It is programmable by a menu item for high or low true. The leading edge of the "true" level indicates the end of the total settling time (relay settling time plus programmed settling time).

3.11.6 IEEE-488 Bus Triggering

To trigger a setup change with an IEEE-488 trigger source, you must send the appropriate IEEE-488 command over the bus: X, talk, or GET, depending on the selected source. Trigger on GET allows the fastest IEEE-488 triggering response. See Section 4 for details on bus triggering.

If one of these commands has been selected as the trigger source, you can also trigger the unit by pressing the MANUAL key unless the unit is in remote.

3.12 RESETTING

The reset operation performs the same functions as cycling power except power-up self-checking. If a master/slave error is detected during reset, the unit will revert to standalone operation. The front panel RESET key is used to initiate a reset operation.

Reset, power-up, and factory default conditions were previously listed in Table 3-2.

3.13 BACKPLANE JUMPERS

The Model 707 backplane has jumpered connections between slots 3 and 4 for the following general purpose signals:

- HI and LO of analog bus #1 (e.g., rows C-F of Model 7072).
- HI, LO, and Guard of analog bus #2 (e.g., rows A-H of Model 7071).

These jumpers can be removed to selectively isolate the signals of slots 1-3 from slots 4-6. If all jumpers are removed, there will be two 3-slot general purpose analog backplanes in one mainframe. An example system configuration using this isolation method is described in Section 2.

The following steps outline the procedure for removing backplane jumpers:

WARNING

Turn off mainframe power and disconnect the line cord. Ensure no voltage is applied from user circuits, then remove all cards.

1. Set the mainframe on a bench. (Slightly raise the bottom edge of the front panel off the bench surface by placing a thin book under the mainframe.) Remove the eight pan-head screws holding the handles to the unit. See Figure 3-20.
2. Remove the six flat-head screws attaching the front panel.
3. Grasping the right side of the front panel, swing it to the left approximately 45° and rest it on its edge.

CAUTION

Do not touch the surface of the backplane to prevent possible contamination from body oil and dirt, which could degrade insulation resistance.

4. The backplane jumpers are called out in Figure 3-21. Remove them by snipping with diagonal cutters.

If it is necessary to clean the connector side of the backplane or re-insert backplane jumpers (Keithley part number J-15) continue with these steps:

5. Remove the two pan-head screws attaching the backplane support bracket, as shown in Figure 3-20, and remove the bracket.
6. Grasping the backplane by its edges, lift it off the backplane support tabs. Swing the backplane to the left and rest it on its edge as shown in Figure 3-22.
7. After soldering on the backplane, remove the flux with Freon® TMS or TE and clean cotton swabs. Take care

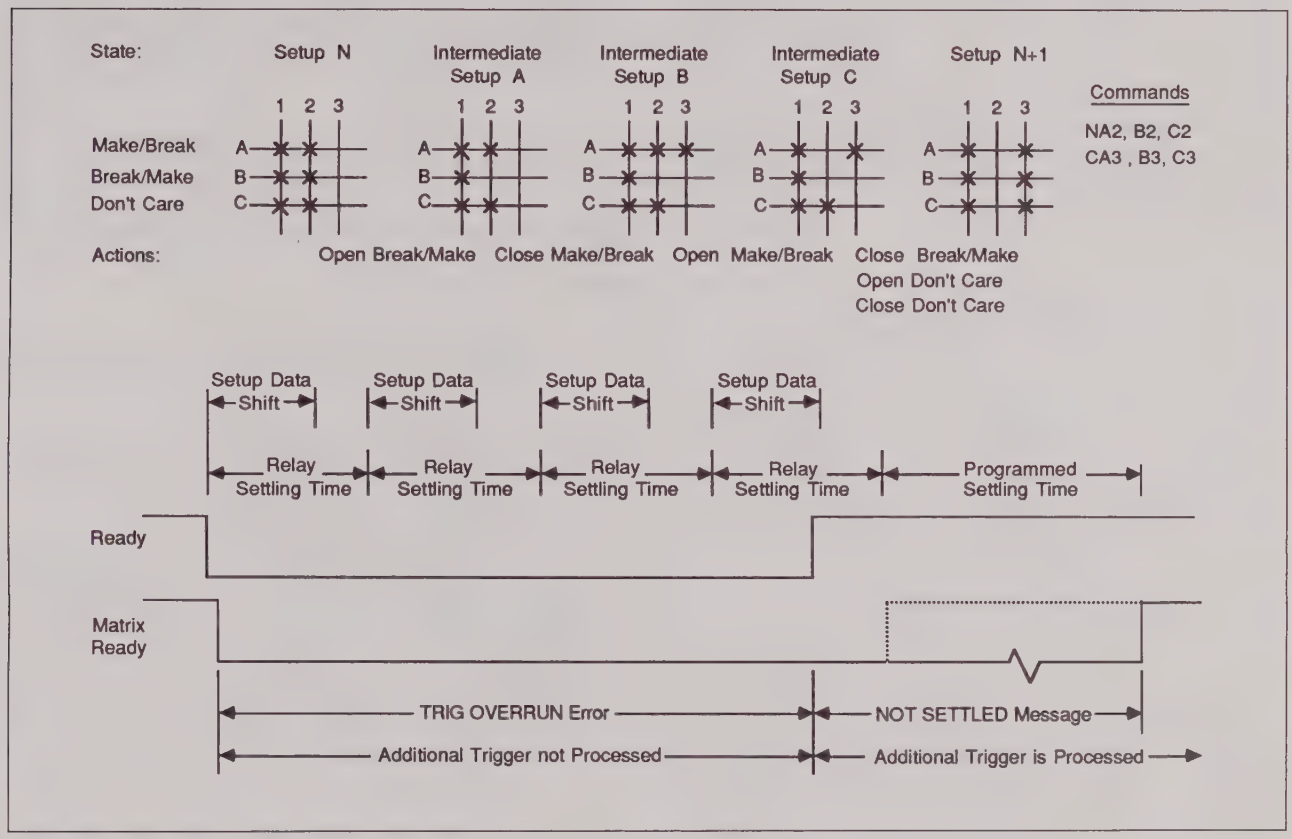


Figure 3-19. Timing with Both Make/Break and Break/Make Rows

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The matrix ready output provides a TTL-compatible signal, as shown previously in Figure 3-12. This signal can be used to inform other instruments when the total settling time is complete. It is programmable by a menu item for high or low true. The leading edge of the "true" level indicates the end of the total settling time (relay settling time plus programmed settling time).

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The following steps outline the procedure for removing backplane jumpers:

1. Turn off mainframe power and disconnect the line cord. Ensure no voltage is applied from user circuits, then remove all cards.
2. Set the mainframe on a bench. (Slightly raise the bottom edge of the front panel off the bench surface by placing a thin book under the mainframe.) Remove the eight pan-head screws holding the handles to the unit. See Figure 3-20.
3. Remove the six flat-head screws attaching the front panel.
4. Grasping the right side of the front panel, swing it to the left approximately 45° and rest it on its edge.

CAUTION
Do not touch the surface of the backplane to prevent possible contamination from body oil and dirt, which could degrade insulation resistance.

5. The backplane jumpers are called out in Figure 3-21. Remove them by snipping with diagonal cutters.

If it is necessary to clean the connector side of the backplane or re-insert backplane jumpers (Keithley part number J-15) continue with these steps:

6. Remove the two pan-head screws attaching the backplane support bracket, as shown in Figure 3-20, and remove the bracket.
7. Grasping the backplane by its edges, lift it off the backplane support tabs. Swing the backplane to the left and rest it on its edge as shown in Figure 3-22.
8. After soldering on the backplane, remove the flux with Freon® TMS or TE and clean cotton swabs. Take care not to spread the flux to other areas. Once the flux has been removed, swab only the affected area with methanol, then blow-dry the card with dry nitrogen gas.

not to spread the flux to other areas. Once the flux has been removed, swab only the affected area with methanol, then blow-dry the card with dry nitrogen gas.

8. If the backplane connectors become contaminated, clean with methanol or distilled water and allow to dry several hours.
9. Reassemble the unit taking care to align the backplane with its supports before attaching the front panel and handles.

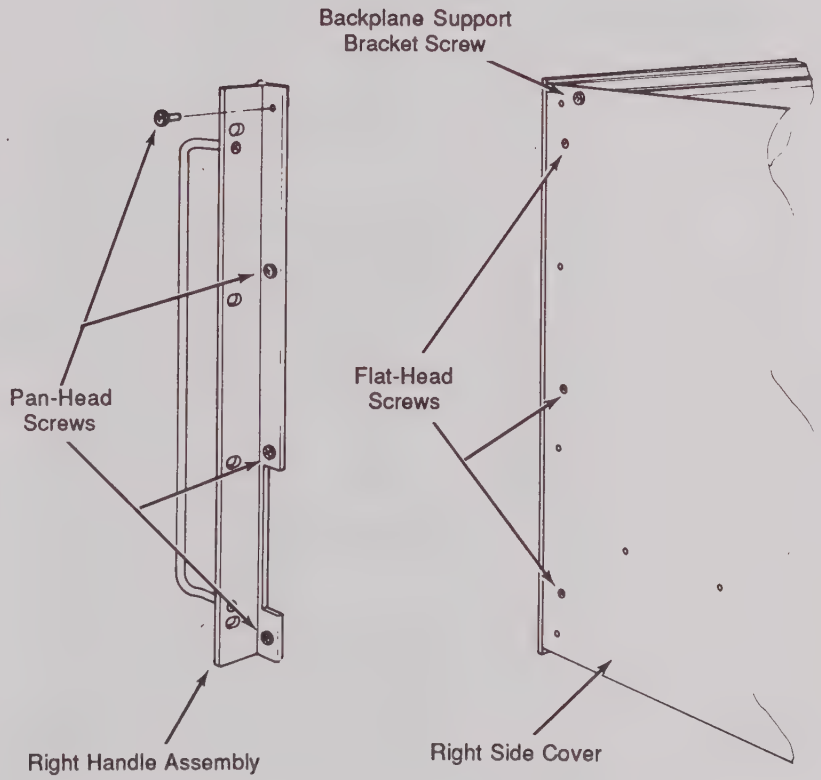


Figure 3-20. Handle and Front Panel Screws

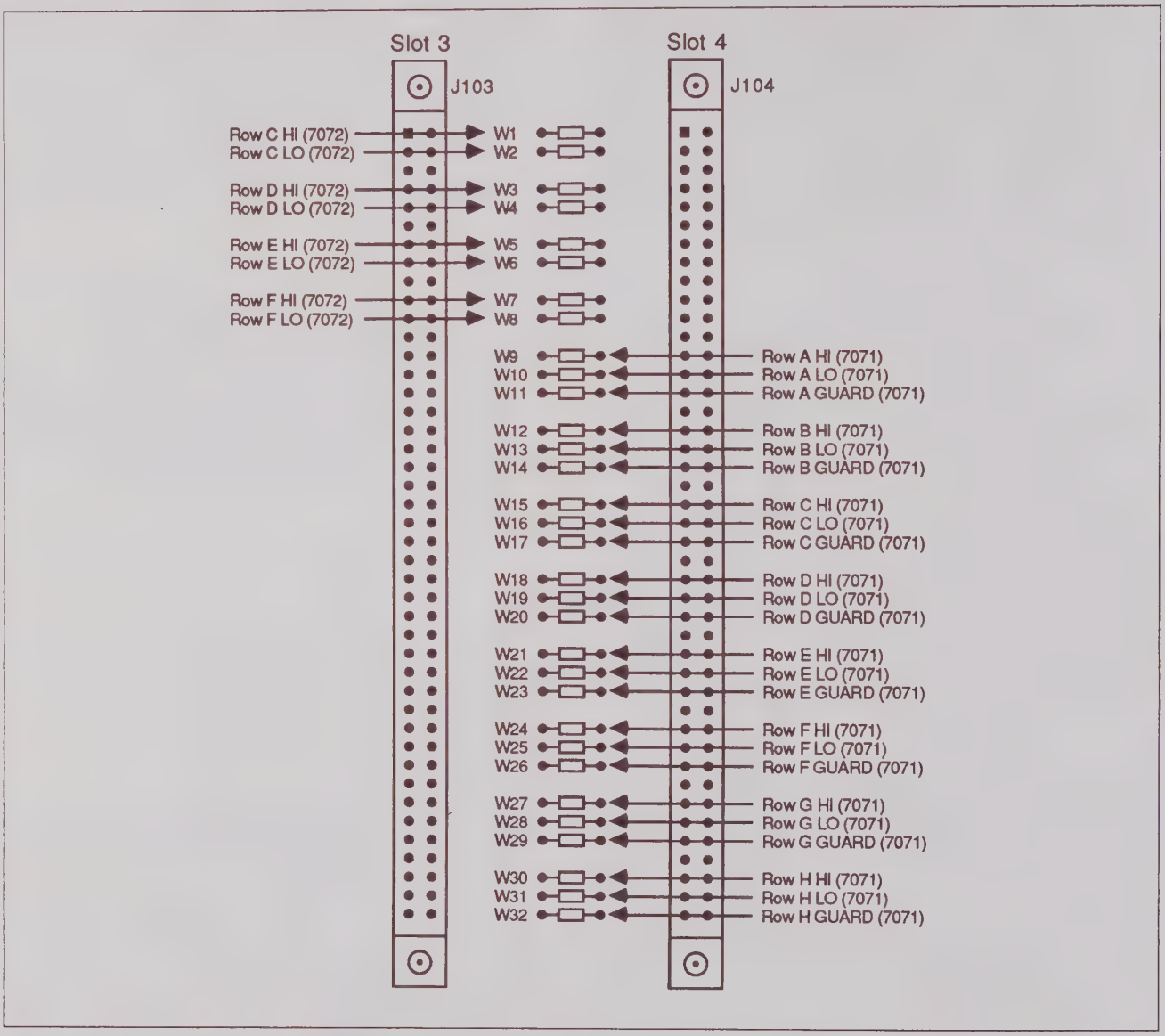


Figure 3-21. Backplane Jumpers

9. If the backplane connectors become contaminated, clean with methanol or distilled water and allow to dry several hours.

10. Reassemble the unit taking care to align the backplane with its supports before attaching the front panel and handles.

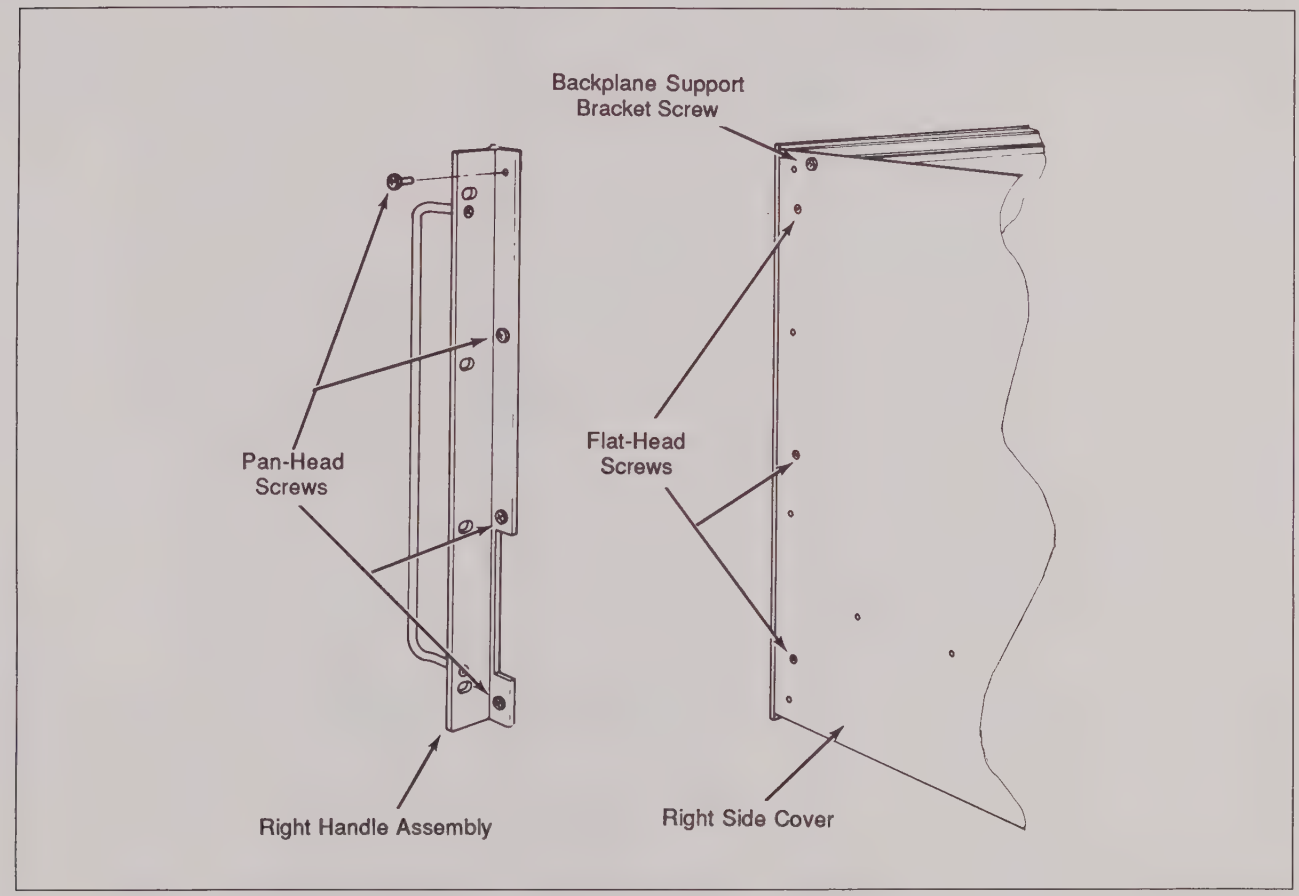


Figure 3-20. Handle and Front Panel Screws

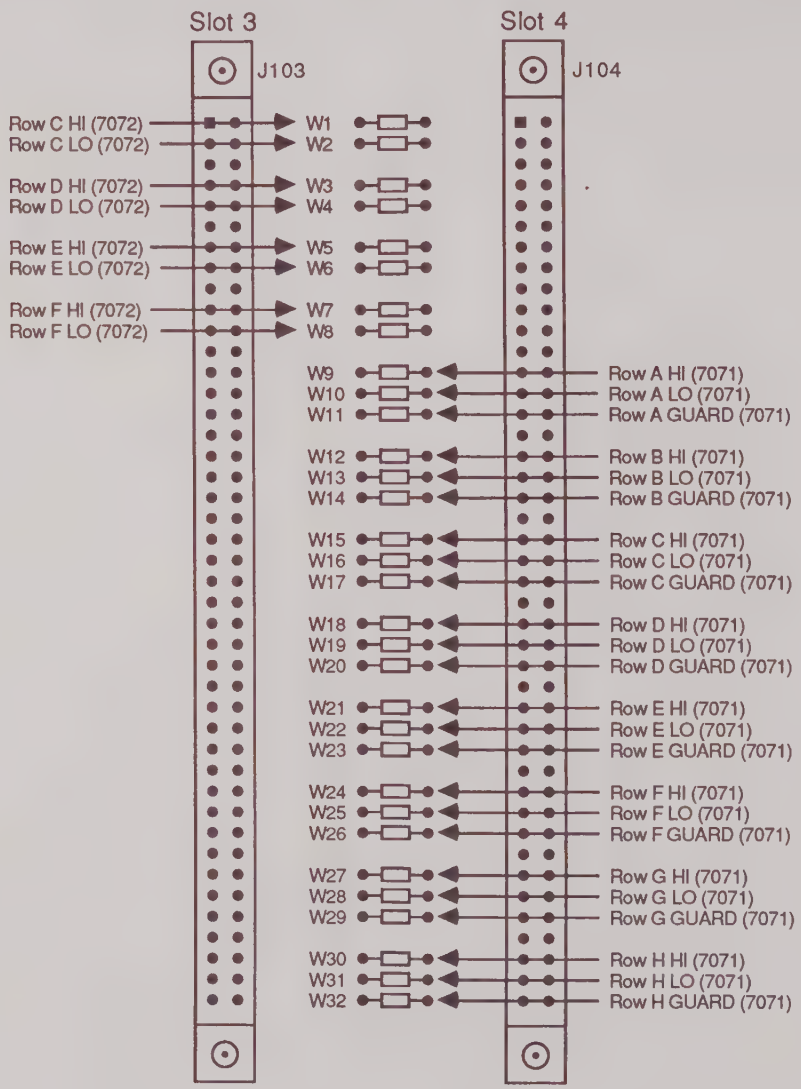


Figure 3-21. Backplane Jumpers

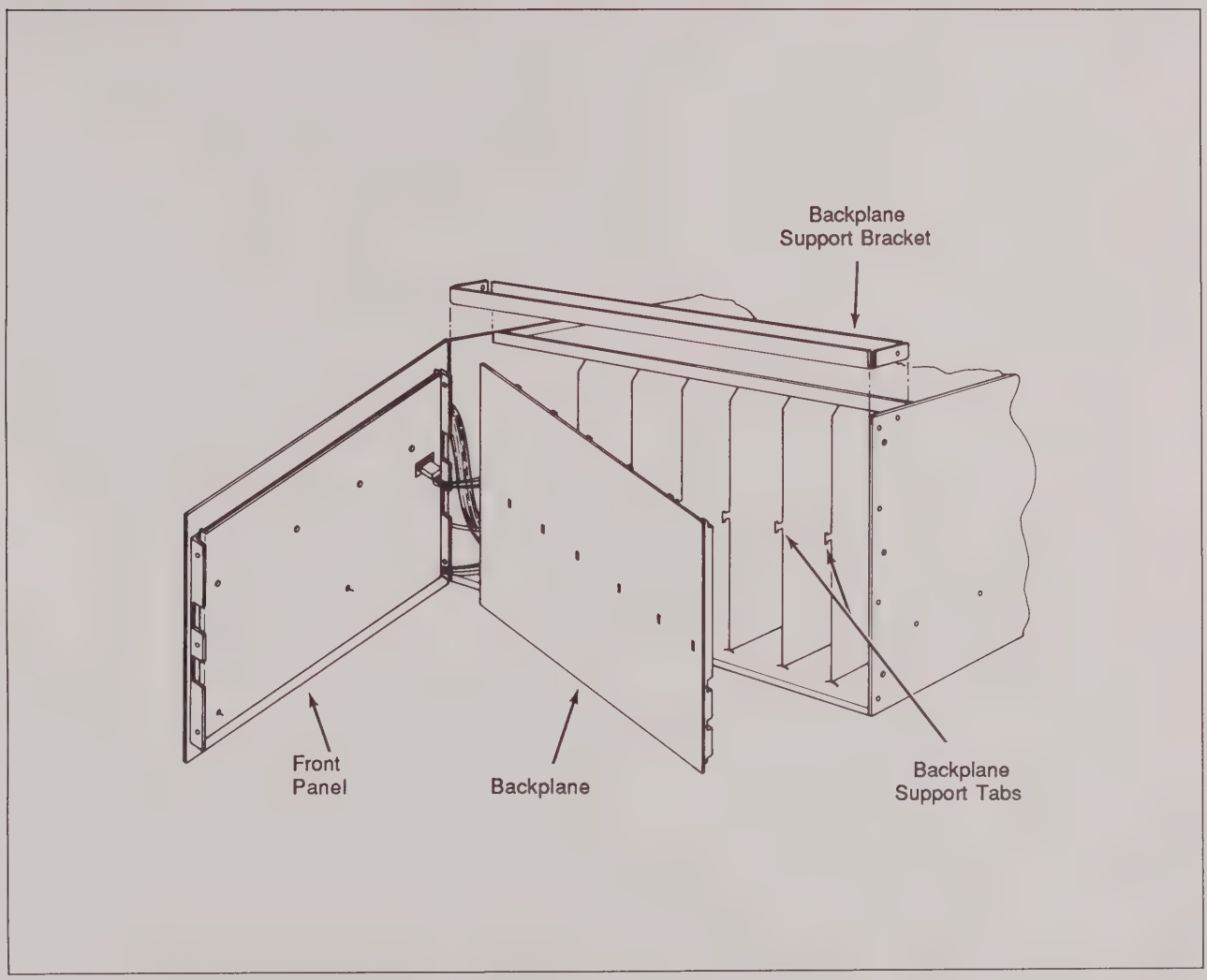


Figure 3-22. Backplane Removal

SECTION 4
IEEE-488 Programming

4.1 INTRODUCTION

This section contains information on programming the Model 707 over the IEEE-488 bus. Detailed instructions for all programmable functions are included, however, information concerning operating modes presented elsewhere is not repeated. Refer to Sections 2 and 3 for information not found in this section.

General information on the IEEE-488 bus is located in Appendix C.

4.2 A SHORT-CUT TO IEEE-488 OPERATION

The paragraphs below take you through a step-by-step procedure to get a Model 707 on the bus to program some basic commands.

Step 1: Connect Your Model 707 to the Controller

With power off, connect the Model 707 to the IEEE-488 interface of the controller using a standard interface cable. Some controllers include an integral cable, while others require a separate cable. Paragraph 4.3 discusses bus connections in detail.

Step 2: Select the Primary Address

The primary address is a way for the controller to refer to each device on the bus individually. Consequently, the primary address of your Model 707 must be the same as the primary address specified in the controller's programming language, or you cannot program the instrument. Keep in mind that each device on the bus must have a different primary address.

The primary address of your Model 707 is set to 18 at the factory, but you can program other values between 0 and 30 by pressing MENU until the present address is displayed and then using the numeric keys to change the primary address. Once the desired value is displayed, press ENTER to program the value. (More detailed information on primary address selection is in paragraph 4.5.)

Step 3: Write Your Program

Even the most basic operations require a simple program to send commands to the instrument. Figure 4-1 shows a flowchart of a program to select make/break and break/make rows, modify crosspoints of a setup stored in memory, send the setup to the relays, and then request data of the current relay setup.

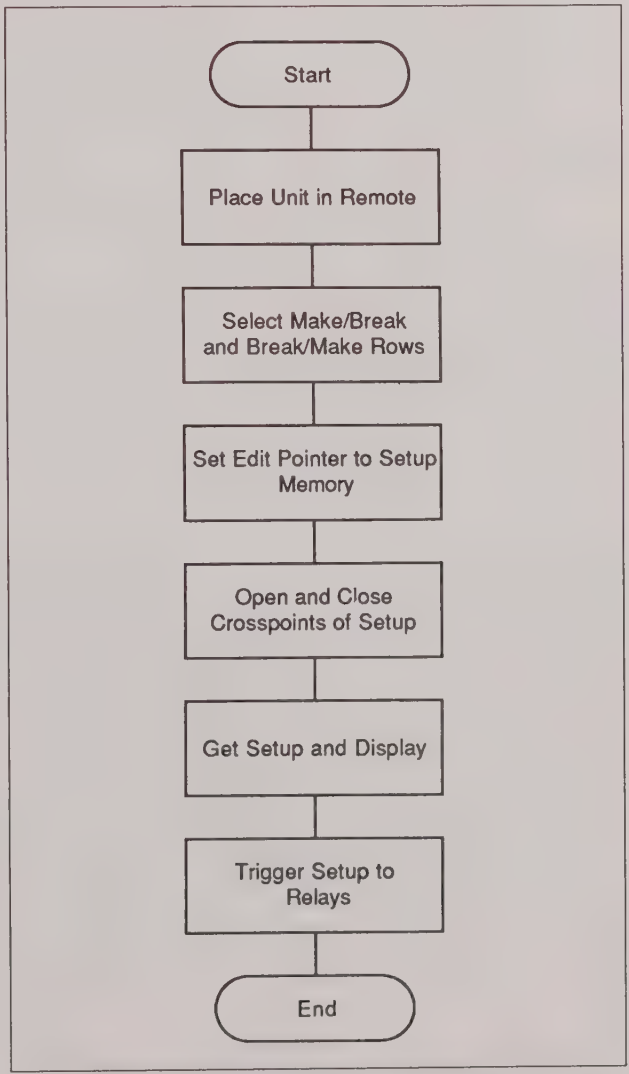


Figure 4-1. Flowchart of Example Program

The corresponding program, written in HP BASIC 4.0 for an HP-9000, Model 310 computer, is written in three parts for this example. The program assumes a primary IEEE-488 address of 18 for the Model 707 and that power-up default conditions exist in the unit.

PROGRAM	COMMENTS
`10 DIM A$[200],C$[200]`	! Dimension crosspoint input and display
`20 REMOTE 718`	! Tell 707 to listen over bus
`30 OUTPUT 718;"U11000 000W00000011X"`	! Select A and B for make/break, G and H for break/make
`40 OUTPUT 718;"E1H1X"`	! Set edit pointer, display setup #1
`50 INPUT "CROSSPOINTS COMMAND",C$`	! Get crosspoint data
`60 IF LEN(C$)=0 THEN 90`	! Check for null string
`70 OUTPUT 718;C$&"X"`	! Send command string to 707
`80 GOTO 50`	! Get more crosspoint data
`90 END`	

Step 4: Open and Close Crosspoints

You can open, close, and clear crosspoints by sending the appropriate command, which is made up of an ASCII letter representing the command, followed by one or more characters for the command options. A number of commands can be grouped together in one string, if desired. The command strings are not opening and closing relays unless the edit pointer of statement 40 is set to zero.

To open and close crosspoints over the bus, simply run the previous program and type in a command string when prompted. Some example strings are given below:

`"P1"`	Clear (open) all crosspoints of setup #1
`"CA55,A56,B49,B50"`	Set (close) crosspoints A55, A56, B49, B50
`"NA55,A56"`	Clear (open) crosspoints A55, A56
`"CA1,A2NB49,B50"`	Set (close) A1, A2 and clear (open) B49, B50

NOTE

Since HP BASIC 4.0 uses a comma to delimit its INPUT statement, and a comma is also used to delimit multiple-option 707 commands, place quotes around the input string when typing in multiple-option commands. An alternative is to use the BASIC statement LINE INPUT rather than INPUT.

Terminate each string by pressing RETURN on the controller keyboard. If a null string is entered, the program ends.

Step 5: Modify Program for Requesting Data

To display or print setup data, you must specify one of the data output formats that sends ASCII characters. Note that a variety of data formats are available, as discussed in paragraph 4.9. The data can be of a setup stored in memory or the current relay setup. Modify the previous program with these statements:

```
90  OUTPUT 718;"U2,1G2X" ! Set data format for setup #1
100 ENTER 718;A$         ! Get stored setup data
110 PRINT A$             ! and print
120 END
```

When the program is run with these statements, it lists the closed crosspoints that you have entered.

Step 6: Modify Program for Triggering

Triggers provide a quick means of copying relay data from a pre-programmed setup to the relays. Each valid trigger causes the next sequential setup to be copied to the relays and the relay pointer to be updated.

Modify the previous program with the following statements:

```
120 PAUSE                ! Wait for controller's Continue key
130 OUTPUT 718;"F1T2X"   ! Enable triggers, select trigger on GET
140 TRIGGER 718          ! Trigger setup #1 to relays
150 END
```

When the Continue key on the controller keyboard is pressed, this program modification triggers setup #1 to the relays. This is because the relay step pointer, which is different from the edit pointer, was set to zero by power-up.

4.3 BUS CONNECTIONS

The following paragraphs provide information needed to connect instrumentation to the IEEE-488 bus.

4.3.1 Cable Connections

The Model 707 is connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors. See Figure 4-2. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, as identified by dark colored screws. (Earlier versions had silver colored screws. Do not use these connectors with the Model 707.)

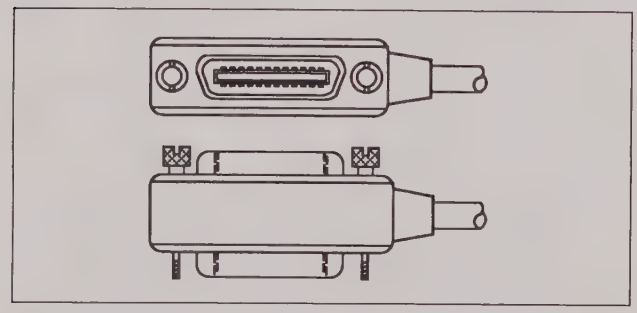


Figure 4-2. IEEE-488 Connector

A typical connecting scheme is shown in Figure 4-3. Each cable normally has a standard connector on each end. These connectors are designed to be stacked to allow a number of parallel connections on one instrument. To avoid possible damage, do not stack more than three connectors on any one instrument.

NOTE

To minimize interference caused by electromagnetic radiation, it is recommended that only shielded IEEE-488 cables be used. The Model 7007-1 and 7007-2 shielded IEEE-488 cables are available from Keithley Instruments.

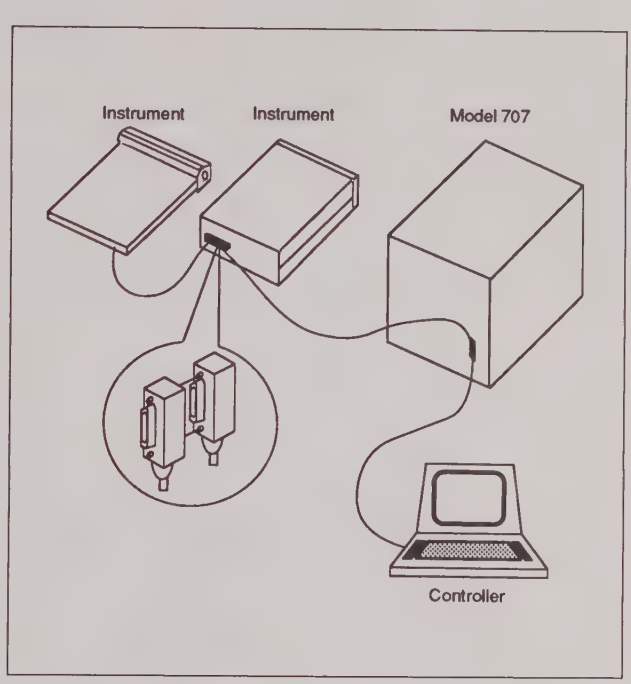


Figure 4-3. IEEE-488 Connections

Connect the cable to the Model 707 as follows:

1. Line up the connector on the cable with the connector on the rear panel of the instrument. Figure 4-4 shows the IEEE-488 connector location.
2. Tighten the screws securely, but do not overtighten them. They break rather easily.
3. Add additional connectors from other instruments, as required.
4. Make sure the other end of the cable is properly connected to the controller. Some controllers have an IEEE-488 type connector, while others do not. Consult the instruction manual of your controller for the proper connecting method.

NOTE

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. Also, the maximum cable length is limited to 20 meters, or 2 meters times the number of devices, whichever is less. Failure to heed these limits may result in erratic bus operation.

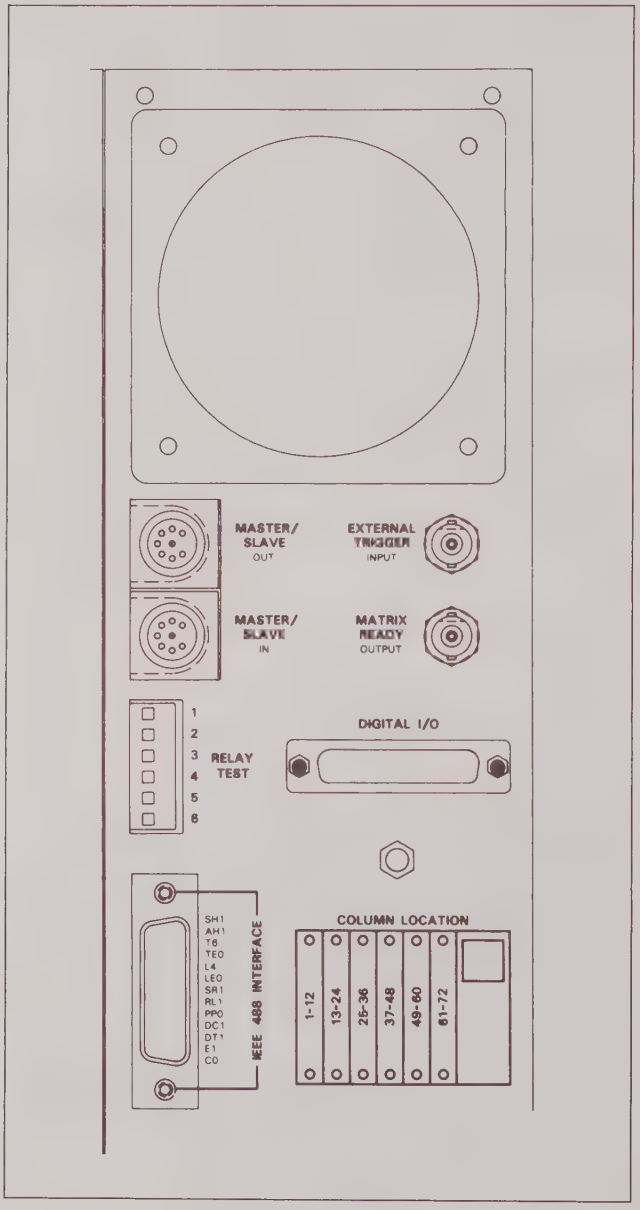


Figure 4-4. IEEE-488 Connector Location

NOTE

In master/slave configurations, only the master unit is connected to the IEEE-488 bus. If slave units are also connected, erratic bus operation results.

Custom cables may be constructed by using the contact assignments listed in Table 4-1 and shown in Figure 4-5.

Table 4-1. IEEE-488 Contact Designation

Number	Contact Designation	IEEE-488 Type
1	DIO1	Data
2	DIO2	Data
3	DIO3	Data
4	DIO4	Data
5	EOI (24)*	Management
6	DAV	Handshake
7	NRFD	Handshake
8	NDAC	Handshake
9	IFC	Management
10	SRQ	Management
11	ATN	Management
12	SHIELD	Ground
13	DIO5	Data
14	DIO6	Data
15	DIO7	Data
16	DIO8	Data
17	REN (24)*	Management
18	Gnd, (6)*	Ground
19	Gnd, (7)*	Ground
20	Gnd, (8)*	Ground
21	Gnd, (9)*	Ground
22	Gnd, (10)*	Ground
23	Gnd, (11)*	Ground
24	Gnd, LOGIC	Ground

*Number in parentheses refers to signal ground return of reference contact number. EOI and REN signal lines return on contact 24.

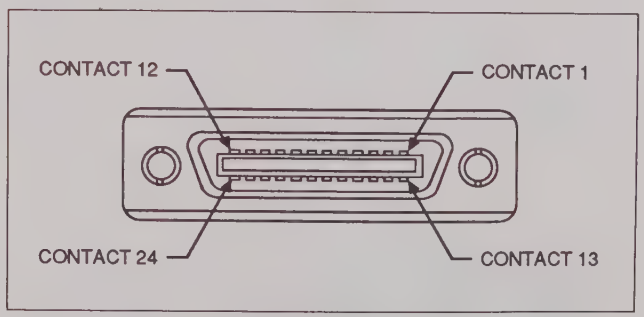


Figure 4-5. Contact Assignments

4.4 INTERFACE FUNCTION CODES

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions. They should not be confused with programming commands found elsewhere in this manual. Interface function codes for the Model 707 are listed in Table 4-2 and are listed for convenience on the rear panel adjacent to the IEEE-488 connector. The codes define Model 707 capabilities as follows:

SH1 (Source Handshake)—SH1 defines the ability of the Model 707 to properly handshake data or command bytes when the unit is a source.

AH1 (Acceptor Handshake)—AH1 defines the ability of the Model 707 to properly handshake the bus when it is an acceptor of data or commands.

T6 (Talker)—The ability of the Model 707 to send data over the bus to other devices is defined by the T6 function. Model 707 talker capabilities exist only after the instrument has been addressed to talk. T6 means that the Model 707 is a basic talker, has serial poll capabilities, and is unaddressed to talk when it receives its own listen address.

TE0 (Extended Talker)—The Model 707 does not have extended talker capabilities.

L4 (Listener)—The L4 function defines the ability of the Model 707 to receive device-dependent data over the bus. Listener capabilities exist only after the instrument has been addressed to listen. L4 means that the Model 707 is a basic listener and is unaddressed to listen when it receives its own talk address.

LE0 (Extended Listener)—The Model 707 does not have extended listener capabilities.

SR1 (Service Request)—The SR1 function defines the ability of the Model 707 to request service from the controller.

RL1 (Remote Local)—The RL1 function defines the capabilities of the Model 707 to be placed in the remote or local states.

PP0 (Parallel Poll)—PP0 means that the Model 707 does not have parallel polling capabilities.

DC1 (Device Clear)—The DC1 function defines the ability of the Model 707 to be cleared (initialized).

DT1 (Device Trigger)—The ability for the Model 707 to have its setups triggered is defined by the DT function.

C0 (Controller)—The Model 707 has no controller capabilities.

E1 (Bus Driver Type)—The Model 707 has open-collector bus drivers.

Table 4-2. Model 707 Interface Function Codes

Code	Interface Function
SH1	Source handshake capability
AH1	Acceptor Handshake capability
T6	Talker (basic talker, serial poll, unaddressed to talk on MLA)
TE0	No Extended Talker capabilities
L4	Listener (basic listener, unaddressed to listen on MTA)
LE0	No Extended Listener capabilities
SR1	Service Request capability
RL1	Remote Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open collector bus drivers

4.5 PRIMARY ADDRESS PROGRAMMING

The Model 707 must receive a listen command before it responds to addressed commands. Similarly, the unit must receive a talk command before it transmits its data. The Model 707 is shipped from the factory with a programmed primary address of 18. The programming examples included in this manual assume that address.

The primary address may be set to any value between 0 and 30 as long as address conflicts with other instruments are avoided. Note that controllers are also given a primary address, so do not use that address either. Most frequently, controller addresses are 0 or 21, but you should consult the controller's instruction manual for details. Whatever primary address you choose, you must make certain that it corresponds with the value specified as part of the controller's programming language.

To check the present primary address or to change to a new one, perform the following procedure:

1. Press the MENU button until the current primary address is displayed. For example, if the instrument is set to primary address 18, the following message is displayed:

   IEEE-488 18

2. To retain the current address, press CANCEL to exit from the menu.
3. To change the primary address, use the numeric buttons and press ENTER. This stores the new address in memory so that the instrument powers up to that address.

NOTE

Each device on the bus must have a unique primary address. Failure to observe this precaution will probably result in erratic bus operation.

4.6 CONTROLLER PROGRAMMING

The programming instructions covered in this section use examples written with Hewlett Packard BASIC version 4.0. This language was chosen because of its versatility in controlling the IEEE-488 bus. This section covers those statements that are essential to Model 707 operation.

NOTE

Controller programming information for using the IBM-PC interfaced through a Capital Equipment Corporation (CEC) IEEE-488 interface is located in Appendix B.

A partial list of HP BASIC 4.0 statements is shown in Table 4-3.

Table 4-3. HP BASIC 4.0 IEEE-488 Statements

Action	BASIC Statement
Transmit string to device 18.	OUTPUT 718;A$
Obtain string from device 18.	ENTER 718;A$
Send GTL to device 18.	LOCAL 718
Send SDC to device 18.	CLEAR 718
Send DCL to all devices.	CLEAR 7
Send remote enable.	REMOTE 7
Cancel remote enable.	LOCAL 7
Serial poll device 18.	SPOLL (718)
Send local lockout.	LOCAL LOCKOUT 7
Send GET to device 18.	TRIGGER 718
Send IFC.	ABORT 7

4.7 FRONT PANEL ASPECTS OF IEEE-488 OPERATION

The following paragraphs discuss aspects of the front panel that are part of IEEE-488 operation, including front panel error messages, IEEE-488 status indicators, and the LOCAL key.

4.7.1 Front Panel Error Messages

The Model 707 has a number of front panel messages associated with IEEE-488 programming. These messages, which are listed in Table 4-4, inform you of certain conditions that occur when sending device-dependent commands to the instrument.

The following paragraphs describe the front panel error messages associated with IEEE-488 programming. Note that the instrument may be programmed to generate an SRQ, and U command status words can be checked for specific error conditions if any of these errors occur. See paragraphs 4.9.13 and 4.9.21.

Table 4-4. Front Panel IEEE-488 Messages

Message	Description
CARD ID ERROR	Power up routine cannot identify one or more matrix cards.
IDDC	Illegal device-dependent command received.
IDDCO	Illegal device-dependent command option received.
M/S ERROR	Master/slave communication or timing error.
NOT IN REMOTE	X received while unit is in LOCAL state.
NOT SETTLED	Unit triggered before total settling time expired.
RAM FAIL	Power-up routine or self-test detected RAM error.
ROM FAIL	Power-up routine or self-test detected program ROM checksum error.
SETUP ERROR	Power-up routine detected checksum errors in one or more setups. (Affected setups are cleared.)
TRIG OVERRUN	Unit triggered before Ready bit is set.

Card Identification Error

A card ID error occurs when the instrument's power-up routine detects a checksum error in the information from one or more matrix cards. The cards in error are indicated by all LEDs in their crosspoint display blocks being lit.

The message remains displayed until the next front panel operation.

IDDC (Illegal Device-Dependent Command) Error

An IDDC error occurs when the unit receives an illegal device-dependent command over the bus. For example, the command string 1X includes an illegal command because the "1" is not part of the instrument's programming language. When an illegal command is received, the instrument briefly displays the IDDC error message.

NOTE

When an IDDC error is detected in a command string, all commands in the string, up to and including the next X, are ignored.

To correct the error condition, send only valid commands. Refer to paragraph 4.9 for device-dependent command programming details. Note that an IDDC error is also flagged in the U1 word, as discussed in paragraph 4.9.21.

Programming Example—To demonstrate an IDDC error, use the following statements:

```
REMOTE 718
OUTPUT 718;''1X''
```

The IDDC error message is briefly displayed when the second statement above is executed.

IDDCO (Illegal Device-Dependent Command Option) Error

Sending the instrument a legal command with an illegal option results in the IDDCO error message being displayed.

For example, the command K9X has an illegal option (9) that is not part of the instrument's programming language. Thus, although the command K is valid, the option is not, and the IDDCO error results.

NOTE

When an IDDCO error is detected in a command string, all commands in the string, up to and including the next X, are ignored.

To correct this error condition, use only valid command options, as discussed in paragraph 4.9. Note that an IDDCO error is also flagged in the U1 word, as discussed in paragraph 4.9.21.

Programming Example—Demonstrate an IDDCO error with the following statements:

```
REMOTE 718
OUTPUT 718;''K9X''
```

Note that the IDDCO error message is briefly displayed when the second statement above is executed.

Master/Slave Error

A master/slave error occurs when a communication or timing error is detected in the closed loop of units. If one or more errors are detected, the message M/S ERROR is displayed.

To simulate the error condition, disconnect a DIN cable from either of the MASTER/SLAVE connectors. The message is displayed when the Model 707 performs the next operation that requires communication among the units.

Not in Remote Error

A not in remote error occurs if the instrument receives an "X" while it is in the local state. The NOT IN REMOTE error message is displayed on the alphanumeric display. This is caused by failing to set the REN line true before addressing the Model 707 to listen. (The HP9000 default is to set REN true.) The statement "REMOTE 7" sets the REN line true; the statement "REMOTE 718" sets the REN line true and addresses unit 18 to listen.

Programming Example—To demonstrate the NOT IN REMOTE error message, type in the following lines:

```
LOCAL 7
OUTPUT 718;''A1X''
```

Note that the NOT IN REMOTE error message is briefly displayed when the program times out.

Not Settled Error

A not settled error occurs when the instrument receives an additional trigger before the settling time has expired. This time period is after assertion of the READY signal and before assertion of the MATRIX READY signal. (See paragraph 3.11 for a complete discussion of trigger timing.) Both READY and MATRIX READY are bits in the SPOLL byte; MATRIX READY is also a rear panel signal.

A trigger during this time period is processed normally. When such a trigger condition occurs, the instrument briefly displays the NOT SETTLED error message.

Programming Example—To demonstrate a not settled situation, type in the following statements:

```
REMOTE 718
OUTPUT 718;''S10X''        ! Set programmed settle
                             time of 10msec
OUTPUT 718;''F1T4XXX''     ! Enable triggers, select
                             trigger on X, trigger 3
                             times
```

Note that the NOT SETTLED message is briefly displayed when the third statement above is executed.

RAM or ROM Failure

A RAM or ROM failure occurs when the power-up routine detects an error, either a RAM error, or a checksum error in program ROM. If an error is detected, a RAM FAIL or ROM FAIL message is displayed and the Model 707 waits for a key press.

Setup Error

A setup error occurs when the Model 707 power-up routine detects a checksum error in one or more setups stored in non-volatile memory. While the message SETUP ERROR is displayed, the affected setups are cleared to all open, then the Model 707 waits for a key press.

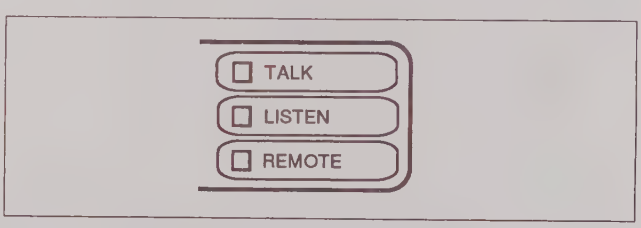
Trigger Overrun (Hardware) Error

A trigger overrun occurs when the instrument is triggered while it is still processing a setup change from a previous trigger and before the READY (for trigger) signal is asserted. (READY is a bit in the SPOLL byte. See paragraph 3.11 for a complete discussion of trigger timing.) The exact trigger stimulus depends on the selected trigger source, as discussed in paragraph 4.9.

Overrun triggers do not affect the instrument except to generate the error message. In other words, the present setup change is not aborted by the overrun trigger stimulus and the trigger is ignored. When such a trigger overrun condition occurs, the instrument briefly displays the TRIG OVERRUN message.

4.7.2 IEEE-488 Status Indicators

The TALK, LISTEN, and REMOTE indicators show the present IEEE-488 status of the instrument. Each of these indicators is briefly described below.



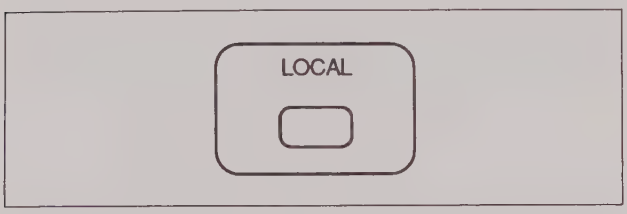
TALK—This indicator is on when the instrument is in the talker active state. The unit is placed in this state by addressing it to talk with the correct MTA (My Talk Address) command. TALK is off when the unit is in the talker idle state. The instrument is placed in the talker idle state by sending it an UNT (Untalk) command, addressing it to listen, or with the IFC (Interface Clear) command.

LISTEN—This indicator is on when the Model 707 is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. Listen is off when the unit is in the listener idle state. The unit can be placed in the listener idle state by sending UNL (Unlisten), addressing it to talk, or by sending IFC (Interface Clear) over the bus.

REMOTE—As the name implies, this indicator shows when the instrument is in the remote state. Note that REMOTE does not necessarily indicate the state of the REN line, as the instrument must be addressed to listen with REN true before the REMOTE indicator turns on. When the instrument is in remote, all front panel keys except for the LOCAL key are locked out. When REMOTE is turned off, the instrument is in the local state, and front panel operation is restored.

4.7.3 LOCAL key

The LOCAL key cancels the remote state and restores local operation of the instrument.



Since all front panel keys except LOCAL are locked out when the instrument is in remote, this key provides a convenient method of restoring front panel operation. Pressing LOCAL also turns off the REMOTE indicator, and returns the display to normal if a message was displayed with the D command. (See paragraph 4.9.4.)

Note that the LOCAL key is also inoperative if the LLO (Local Lockout) command is in effect.

4.7.4 Simultaneous Front Panel and Bus Operation

Fundamentally, there is no reason why you cannot control the instrument simultaneously from both the front panel and over the IEEE-488 bus. However, the following points should be kept in mind.

1. All front panel keys except for LOCAL are inoperative while the Model 707 is in remote (REMOTE on). The unit is placed in remote by addressing it to listen with the REN line true. Thus, to control the unit from the front panel, it is necessary to press LOCAL after programming over the bus. Note that LOCAL is also inoperative if the LLO (Local Lockout) command is in effect.
2. Front panel parameter modification should always be completed before attempting to use bus control. For example, you should not attempt to program a setup over the bus while editing a setup from the front panel.

4.8 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands such as DCL that have the same general meaning regardless of the instrument. Commands supported by the Model 707 are listed in Table 4-5 which also lists BASIC statements necessary to send each command. Note that commands requiring that a primary address be specified assume that the Model 707 primary address is set to 18 (its factory default address).

Table 4-5. General Bus Commands and Associated BASIC Statements

Command	HP BASIC 4.0 Statement	Effect on Model 707
REN	REMOTE 7	Goes into effect when next addressed to listen.
IFC	ABORT 7	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT 7	LOCAL key locked out.
GTL	LOCAL 718	Cancel remote, restore front panel operation.
DCL	CLEAR 7	Returns to default conditions.
SDC	CLEAR 718	Returns to default conditions.
GET	TRIGGER 718	Triggers setup change with GET source.

4.8.1 REN (Remote Enable)

The remote enable command is sent to the Model 707 by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote state before you attempt to program it over the bus. Simply setting REN true does not actually place the instrument in the remote state. Instead the instrument must be addressed to listen after setting REN true before it goes into remote.

Note that the instrument need not be in remote to be a talker.

Programming Example—This sequence is automatically performed by computer when the following is typed into the keyboard:

```
REMOTE 718
```

After the RETURN key is pressed, the instrument is in the remote state, as indicated by the REMOTE light. If not, check to see that the instrument is set to the proper primary address 18, and check to see that the bus connections are properly made.

Note that all front panel controls except LOCAL (and, of course, POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL key.

4.8.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 707 in the local, talker and listener idle states. The unit responds to the IFC command by cancelling front panel TALK or LISTEN lights, if the instrument was previously placed in one of those states.

Programming Example—Before demonstrating the IFC command, turn on the TALK indicator with the following statements:

```
ENTER 718;A$
```

At this point, the TALK light should be on. The IFC command can be sent by entering the following statement into the computer:

```
ABORT 7
```

After the RETURN key is pressed, the TALK indicator turns off, indicating that the instrument has gone into the talker idle state.

4.8.3 LLO (Local Lockout)

The LLO command is used to prevent local operation of the instrument. After the unit receives LLO, all of its front panel controls except POWER are inoperative.

Programming Example—The LLO command is sent by entering the following statement:

```
REMOTE 718
LOCAL LOCKOUT 7
```

After the second statement is executed, the instrument's front panel controls are locked out, including the LOCAL key.

To restore front panel operation after asserting LLO, as in the following example:

```
LOCAL 7
```

4.8.4 GTL (Go To Local) and Local

The GTL command is used to take the instrument out of the remote state. Operation of the front panel keys will also be restored by GTL unless LLO is in effect. To cancel LLO, you must set REN false.

Programming Example—Place the instrument in the remote state with the following statement:

```
REMOTE 718
```

Now send GTL with the following statement:

```
LOCAL 718
```

Note that the instrument goes into the local state, and that operation of the front panel keys has now been restored (assuming that LLO is not in effect).

4.8.5 DCL (Device Clear)

The DCL command may be used to clear the Model 707 and return it to its power-up default conditions (see Table 4-6). Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 707 receives a DCL command, it returns to the power-up default conditions. DCL does not affect the programmed primary address.

Programming Example—Place the unit in an operating mode that is not a power-up default condition. Now enter the following statement from the controller keyboard:

```
CLEAR 7
```

When the RETURN key is pressed, the instrument returns to the power-up default conditions.

4.8.6 SDC (Selective Device Clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL. Any devices on the bus that are addressed to listen are cleared. When the Model 707 receives the SDC command, it returns to the power-up default conditions.

Programming Example—Place the unit in an operating mode that is not a power-up default condition. Now enter the following statement from the controller keyboard:

```
CLEAR 718
```

This sends the following IEEE-488 commands: UNT UNL LISTEN 18 SDC. When the statement is executed, the instrument(s) returns to the default configuration.

Table 4-6. Factory Default, Power-up, and DCL/SDC Conditions

Parameter	Factory Default	Power-up, DCL/SDC	Description
Relays	All opened	All opened	—
Stored Setups	All cleared	Not affected	—
Relay Step	000	000	Point to relays
Memory Step	001	001	Point to setup 1
Master/Slave	Stand-alone	(Notes 2, 3)	—
IEEE-488 Address	18 (Note 1)	Not affected	—
External Trigger	A0	A0	Falling edge triggers
Matrix Ready	B0	B0	Negative true
Display	DX	DX	Normal alphanumeric display
Edit Pointer	E0	E0	Point to relays
Trigger Enable	F0	F0	Triggers disabled
Data Format	G0	G0	Full output, all data sent in one talk
EOI/Hold-off	K0	K0	Both enabled
SRQ	M0	M0	Disabled
Digital Output	O000	O000	Output lines low
Programmed Settling Time	S0	S0	0msec
Trigger Source	T7	T7	External trigger
Make/Break Rows	V00000000	Not affected	None selected
Break/Make Rows	W00000000	Not affected	None selected
Terminator	Y0	Y0	<CR><LF>

Notes:

1. The IEEE-488 address is not affected by the Restore (R0) command.
2. Units that previously were stand-alone or slave power up as stand-alone. They become slave units when a master unit initializes a master/slave loop, either upon power up or with a menu selection.
3. DCL/SDC does not affect master/slave state. DCL/SDC does clear slaves.

4.8.7 GET (Group Execute Trigger)

GET may be used to initiate a Model 707 setup change if the instrument is placed in the appropriate trigger source. More information on triggering is located in paragraph 4.9.

Programming Example—With triggers enabled, type in the following statements to place the instrument in the correct trigger source for purposes of this demonstration:

```
REMOTE 718
OUTPUT 718;''T2F1X''
```

Now trigger the setup change be sending GET with the following statement:

```
TRIGGER 718
```

This sends IEEE-488 commands UNT UNL LISTEN 18 GET. When the RETURN key is pressed, the setup change is triggered. (The command TRIGGER 7 just sends GET. Any other listeners are triggered when the RETURN key is pressed.)

4.8.8 SPE, SPD (Serial Polling)

The serial polling sequence is used to obtain the Model 707 serial poll byte. The serial poll byte contains important information about internal functions, as described in paragraph 4.9.13. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the serial poll byte from the Model 707.

Programming Example—The SPOLL statement automatically performs the serial poll sequence. To demonstrate serial polling, enter the following statements into the computer:

```
S=SPOLL(718)
PRINT''SPOLL BYTE='';S
```

After the first statement, the controller conducts the serial polling sequence. After the second statement is executed, the decimal value of the serial poll byte is displayed on the controller CRT.

4.9 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are the most important commands associated with instrument programming because they control most instrument operating modes. All front panel modes (such as trigger source and settling time), as well as some modes not available from the front panel (like SRQ and terminator) can be programmed with these commands. Equivalent device-dependent commands for front panel keys are listed in Appendix D.

Command Syntax Each command is made up of a single ASCII capital letter followed by one or more numbers or letters representing an option or options of that command. For example, the trigger source can be set over the bus by sending the letter "T" followed by a number representing the trigger option. T1X would be sent to trigger on talk. The IEEE-488 bus actually treats these commands as data, in that they are sent with the ATN line false.

Some commands permit more than one option; these must be separated with commas. As an example, the close crosspoints commands has the general format as shown:

Crc(,rc)...(,rc)

Here the "rc" options are row and column addresses, while the commas indicate the necessary delimiters. The parentheses indicate that the option and associated delimiter are optional.

NOTE
Do not include parentheses in actual command strings.

Multiple Commands A number of commands can be grouped together in one command string, which is generally terminated by the "X" character. This character tells the instrument to execute the command or command string as described in paragraph 4.9.24. Commands sent without the X character are not executed at that particular time, but they are stored within an internal command buffer for later execution when the X character is finally received.

If a particular command occurs "n" times in a command string, then the "nth" occurrence is the only one used, i.e., T0T2T4X appears to the Model 707 as T4X.

Invalid Commands If an invlaid command is sent as part of the command string, no commands in the string are executed. Under these conditions, the instrument displays a front panel error message (IDDC or IDDCO), as covered in paragraph 4.7, and it can be programmed to generate an SRQ (Service Request), as discussed in paragraph 4.9.13. Checking is done as syntactical groups of characters are received.

Some typical examples of valid command strings include:

A0X	Single command string.
A0T6X	Multiple command string.
P 0X	Space is ignored.
Z15,0X	Multiple-option command string (options separated by commas).

Typical invalid command strings include:

1X	Invalid command as 1 is not a valid command.
K7X	Invalid command option as 7 is not a valid option of the K command.
CA400X	Invalid option (maximum column address is 360).
Z0100X	Multiple-option command without the necessary separating commas.

Order of Command Execution Device-dependent commands are not necessarily executed in the order received. Rather, each instrument always executes them is a specific order. The order of execution for the Model 707 is summarized in Table 4-7. Note that the X command is listed first since it is the character that forces the execution of the rest of the commands.

If you wish to force a particular order of execution, simply include the execute (X) character after each command option grouping in the command string. For example, the following string would be executed in the received order:

T6XA1XR0X

Table 4-7. Order of Command Execution

Order	Command	Description
1	X	Execute DDCs
2	R	Restore factory default conditions
3	L	Download setups from controller to Model 707
4	E	Set the edit pointer
5	I	Insert a blank setup in memory
6	Q	Delete a setup from memory
7	P	Clear all crosspoints at specified setup
8	Z	Copy a setup from memory or relays to memory or relays
9	V	Select rows from make/break
10	W	Select rows for break/make
11	N	Open crosspoints of setup indicated by edit pointer
12	C	Close crosspoints of setup indicated by edit pointer
13	A	Select trigger edge of External Trigger pulse
14	B	Select logic sense of Matrix Ready signal
15	D	Display a user message
16	F	Enable/disable triggers
17	G	Select data output format
18	J	Execute ROM/RAM/display self-test
19	K	Select EOI and hold-off on X
20	M	Set the SRQ mask
21	O	Set the digital output
22	S	Program the settling time
23	T	Select the trigger source
24	U	Request status
25	Y	Select terminator characters
26	H	Hit a front panel key

Device-dependent Command Summary All Model 707 device-dependent commands are summarized in Table 4-8, which also lists respective paragraphs where more detailed information on each command may be found.

Table 4-8. Device-Dependent Command Summary

Mode	Command	Description	Para.
External Trigger	A0 A1	Falling edge triggers Model 707 Rising edge triggers Model 707	4.9.1
Matrix Ready	B0 B1	Negative true Matrix Ready output Positive true Matrix Ready output	4.9.2
Close Crosspoint	Crc(,rc)...(,rc)	Close crosspoints of setup indicated by edit pointer (rows A-H, cols. 1-360)	4.9.3
Display	Dccccccccccccc DX	Display ASCII characters (14 max.) Return alphanumeric display to normal	4.9.4
Edit Pointer	E0 En	Point to current relay setup Point to stored relay setup (1-100)	4.9.5
Enable/Disable Triggers	F0 F1	Disable triggers Enable triggers	4.9.6
Data Format	G0 G1 G2 or G3 G4 G5 G6 G7	Full output, all data in one talk Full output, one mainframe row per talk Inspect output, all data in one talk Condensed output, all data in one talk Condensed output, one mainframe per talk Binary output, all data in one talk Binary output, one mainframe per talk	4.9.7
Hit Key	Hn	Emulate front panel key press (1-41)	4.9.8
Insert Blank Setup	In	Insert blank setup in memory (1-100)	4.9.9
Self-test	J0	Perform self-test	4.9.10
EOI and Hold-off	K0 K1 K2 K3 K4 K5	Send EOI, hold-off on X until Ready No EOI, hold-off on X until Ready Send EOI, do not hold-off on X No EOI, do not hold-off on X Send EOI, hold-off on X until Matrix Ready No EOI, hold-off on X until Matrix Ready	4.9.11
Download Setups	Lbbb...X	Download setups from controller to Model 707	4.9.12
SRQ	M0 M1 M2 M4 M8 M16 M32 M128	SRQ disabled not used Front panel key press Digital I/O interrupt Matrix Ready Ready for trigger Error not used	4.9.13
Open Crosspoint	Nrc(,rc)...(,rc)	Open crosspoints of setup indicated by edit pointer (rows A-H, cols. 1-360)	4.9.14
Digital Output	Onnn	Set states of digital output lines (000-255)	4.9.15

Table 4-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Para.
Clear Crosspoints	P0 Pn	Open all crosspoint relays Clear all crosspoints of stored setup (1-100)	4.9.16
Delete Setup	Qn	Delete setup from memory (1-100)	4.9.17
Restore Defaults	R0	Restore factory defaults	4.9.18
Programmed Settling Time	Sn	Program settling time in msec (0-65000)	4.9.19
Trigger	T0 or T1 T2 or T3 T4 or T5 T6 or T7 T8 or T9	Trigger on talk Trigger on GET Trigger on X Trigger on External Trigger pulse Trigger on front panel MANUAL key only	4.9.20
Status	U0 U1 U2,n U3 U4 U5,u U6 U7 U8	Send machine status word Send error status word Output setup "n" (0-100) with current G format Send RELAY STEP pointer Send number of slaves Send model number of each card in unit "u" (0-4) Send relay settling time Send digital input of unit Send RELAY TEST input	4.9.21
Make/Break	Vabcdefgh	Select rows for make/break operation (00000000 - 11111111)	4.9.22
Break/Make	Wabcdefgh	Select rows for break/make operation (00000000 - 11111111)	4.9.23
Execute	X	Execute commands	4.9.24
Terminator	Y0 Y1 Y2 Y3	<CR><LF> <LF><CR> <CR> <LF>	4.9.25
Copy Setup	Z0,n Zn,0 Zm,n	Copy current relay setup to memory location "n" (1-100) Copy setup from memory location "n" (1-100) to relays Copy setup from location "m" (0-100) to location "n" (0-100)	4.9.26

4.9.1 A - External Trigger

Purpose To select which edge of an external trigger pulse initiates a trigger.

Format **An**

Parameters A0 = Falling edge triggers Model 707
A1 = Rising edge triggers Model 707

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to A0 (falling edge).

Description The A command allows you to program the Model 707 for triggering on a TTL-compatible falling or rising edge signal at the External Trigger input jack. A trigger signal increments the RELAY STEP pointer and copies the setup indicated by the new value from memory to the relays.

Figure 4-6 shows example trigger pulses. Trigger on external must be the selected source (T command) and triggers must be enabled (F command).

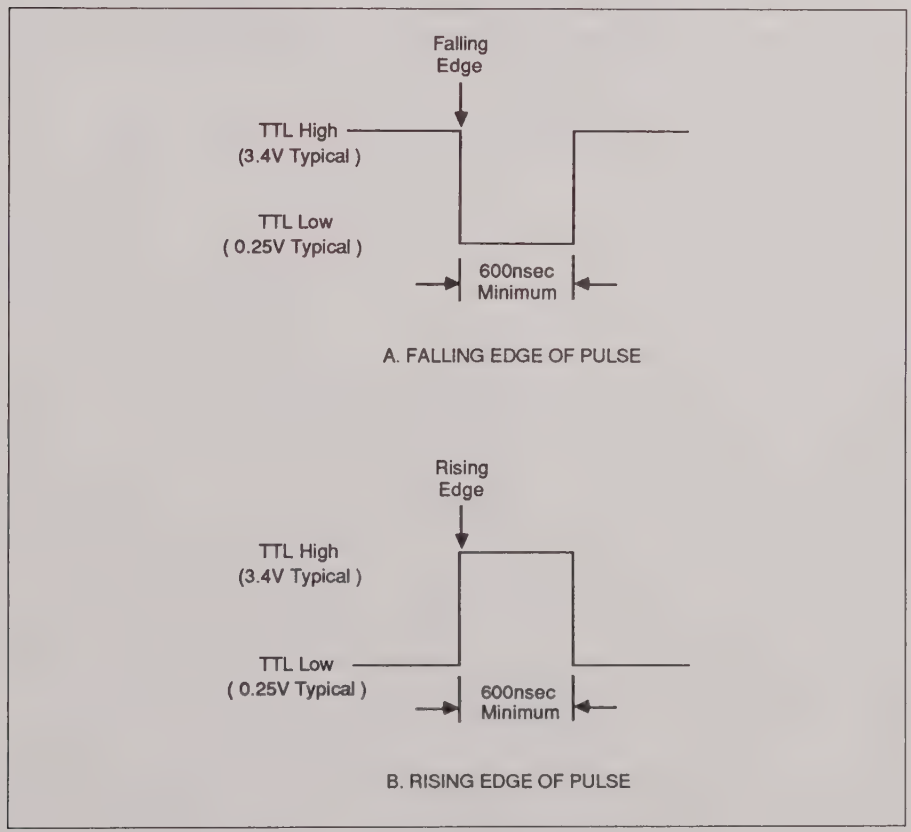


Figure 4-6. External Trigger Pulse

Programming Note This command is equivalent to a front panel menu selection.

Programming Examples

```
10 OUTPUT 718;''A1X''    ! Select rising edge pulse to trigger
20 OUTPUT 718;''A0X''    ! Select falling edge to trigger
```

4.9.2 B - Matrix Ready

Purpose To select the logic sense of the rear panel Matrix Ready signal.

Format **Bn**

Parameters B0 = Negative true Matrix Ready output
B1 = Positive true Matrix Ready output

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to B0 (negative true).

Description The B command allows you to program the TTL-compatible Matrix Ready output as a high- or low-true signal. This signal goes false when the relays are switched; it goes true after completion of the (hardware) relay settling time and (user) programmed settling time. Figure 4-7 shows example Matrix Ready signals.

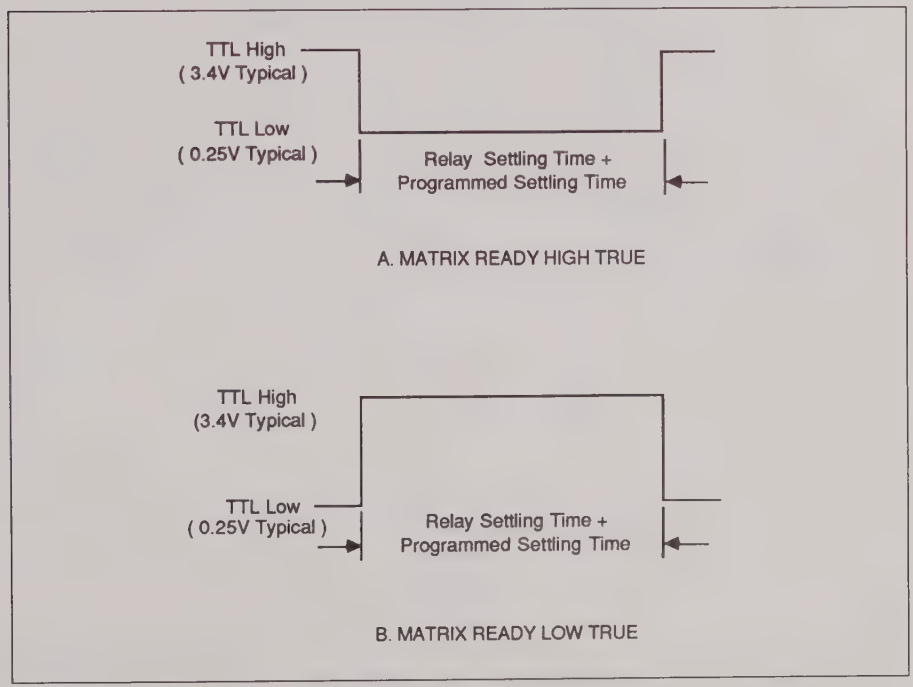


Figure 4-7. Matrix Ready Pulse

Programming Notes

1. The Matrix Ready signal is negated by anything that causes a change to a relay state even if no relays actually change state (e.g., closing an already closed relay).
2. Changing the logic sense of the Matrix Ready signal does not change the logic sense of the Matrix Ready bit in the serial poll byte.
3. This command is equivalent to a front panel menu selection.

Programming Examples

```
10 OUTPUT 718;"B1X"     ! Select positive true Matrix Ready
20 OUTPUT 718;"B0X"     ! Select negative true Matrix Ready
```

4.9.3 C - Close Crosspoint

Purpose To close crosspoints in a setup.

Format **Crc(,rc)...(,rc)**

Parameters
r = Row A to row H
c = Column 1 to column 360

Description The C command closes crosspoints in the setup indicated by the edit pointer. If the edit pointer indicates the current relay setup (zero), the specified crosspoint relays are closed immediately. If the edit pointer indicates a setup stored in memory (1-100), the specified crosspoints are set.

Programming Notes
1. Do not include parentheses in command strings. They indicate that the option and associated comma delimiter are optional.
2. Up to 25 crosspoints per mainframe can be specified in one close command (with a master and four slaves, the limit is 125 crosspoints). In the same command string, up to 25 crosspoints per mainframe can be opened. If either limit is exceeded, an IDDCO results.
3. The maximum value of the column parameter depends on the configuration (72 for stand-alone, 360 for master with four slave units). An IDDCO results if the maximum value is exceeded.
4. This command is equivalent to multiple front panel key presses or light pen operation(s).

Programming Examples

```
10 OUTPUT 718;''CA55X''                    ! Close one crosspoint
20 OUTPUT 718;''CA55,A56,B49,B50X''        ! Close multiple crosspoints
```

4.9.4 D - Display

Purpose To write messages on the front panel alphanumeric display of a stand-alone or master unit.

Format **Dccccccccccccc**

Parameters c = ASCII character (14 maximum)

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to DX (return alphanumeric display to normal operation).

Description The D command allows you to display messages on the front panel alphanumeric display of a stand-alone or master Model 707. To send a message, simply follow the D command with appropriate ASCII characters. Many displayable ASCII characters can be sent, including numbers or upper case characters. Characters that can be displayed include: 0-9, A-Z, arithmetic and most punctuation symbols.

Programming Notes

1. As with other device-dependent commands, the D command string should be terminated with the X.
2. Spaces in the command string are displayed.
3. The maximum number of characters is 14; any extra characters in the string are ignored. If there are fewer than 14 characters between the D and X, the characters are left-justified and the rest of the display is blank.
4. To return the alphanumeric display to normal, send DX, perform device clear, or return the Model 707 to the local state.

Programming Example

```
10 OUTPUT 718;''DMODEL 707X''        ! Display MODEL 707 message
```

4.9.5 E - Edit Pointer

Purpose To set the edit pointer.

Format **En**

Parameters n = 0 Current relay setup
n = 1 to 100 Stored relay setup

Default Upon power-up, or after receiving a DCL, SDC or R0X command, the instrument defaults to E0 (current relay setup).

Description With the edit pointer, you can select which setup is affected by subsequent close (C) and open (N) commands. This can be the current relay setup (zero) or one of the stored setups (1-100).

Programming Notes

1. The edit pointer is not reflected on the front panel display (i.e., MEMORY or RELAYS LED). The edit pointer value is also independent of the RELAY STEP and MEMORY STEP values.
2. When using the edit pointer, it is not necessary to use the COPY keys, as you are closing/opening crosspoints relays or setting/clearing stored crosspoints directly and not just turning on/off crosspoint LEDs.

Programming Examples

```
10 OUTPUT 718;"E0X"    ! Point to relays
20 OUTPUT 718;"E50X"   ! Point to stored setup 50
```

4.9.6 F - Enable/disable Triggers

Purpose To enable/disable triggers.

Format **Fn**

Parameters F0 = Disable triggers
F1 = Enable triggers

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to F0 (triggers disabled).

Description With the F command you control whether the Model 707 responds to a trigger (from the external trigger connection, over the IEEE-488 bus, or a front panel key). A trigger increments the RELAY STEP pointer and copies the setup indicated by the new value from memory to the relays.

Programming Notes
1. The ENABLE indicator of the TRIGGER group lights when triggers are enabled.
2. It is good programming practice to disable triggers before changing the trigger source.
3. This command is equivalent to a single front panel key press.

Programming Example

```
10 OUTPUT 718;"F1X"  ! Enable triggers
```

4.9.7 G - Data Format

Purpose To select the output format of the data sent from the current relay setup or a setup stored in memory.

Format **Gn**

Parameters
G0 = Full output format, all data sent in one talk
G1 = Full output format, one row of one mainframe per talk
G2 or G3 = Inspect output format, all data sent in one talk
G4 = Condensed output format, all data sent in one talk
G5 = Condensed output format, one mainframe per talk
G6 = Binary output format, all data sent in one talk
G7 = Binary output format, one mainframe per talk

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to G0 (full output format, all data sent in one talk).

Description The G command specifies the format of crosspoint data sent by the Model 707 over the IEEE-488 bus in response to the U2 command. Data is sent about the setup indicated by "U2,n" command (either the current relay setup or a stored setup). You can control the data format and quantity sent at a time. The full, condensed, and binary formats list the open/closed states of every crosspoint in the setup; the inspect format shows only closed crosspoints.

G0, G1 = Full output format

With the G0/G1 full output formats, the open/closed states of all crosspoints in a setup are sent in printable ASCII. An ASCII "–" represents an open crosspoint and an ASCII "X" represents a closed crosspoint. For G0, all data is sent in one talk; for G1, the data from one row of one mainframe is sent per talk. An example of these formats is shown in Figure 4-8 for the example setup of Table 4-9.

G2, G3 = Inspect output format

With the G2/G3 inspect output formats, the row/column address of each closed crosspoint in a setup is sent in printable ASCII. An ASCII letter (A-H) represents a row and an ASCII string of up to three numbers (0-360) represents a column. Successive crosspoints are separated with a comma. All data is sent in one talk. These formats are shown in Figure 4-9 for the example setup of Table 4-9.

G4, G5 = Condensed output format

The G4/G5 condensed output formats specify the states of all crosspoints with eight bits representing the eight crosspoints of a column. A set bit indicates a closed crosspoint. The hexadecimal representation of the binary value formed by these eight bits is sent as two printable ASCII characters. For G4, all data is sent in one talk; for G5, the data from one mainframe is sent per talk. An example of these formats is shown in Figure 4-10 for the example setup of Table 4-9.

G6, G7 = Binary output format

The G6/G7 binary output formats specify the states of all crosspoints with an 8-bit group of bits representing the eight crosspoints of a column. A set bit indicates a closed crosspoint. For G6, all data is sent in one talk; for G7, the data from one mainframe is sent per talk. These formats are shown in Figure 4-11 for the example setup of Table 4-9.

Table 4-9. Example Setup of Master/Slave Configuration

Unit	Closed Crosspoints
Master	A1, A2, B19, B20, C27, C28, D37, D38, F61, F62
Slave 1	A73, A74, C85, C86, E121, E122
Slave 2	A187, A188, H205, H206
Slave 3	A223, A224, H265, H266
Slave 4	G301, G302, A313, A314, H337, H338, E355, E356

Obtaining Data

Generally, data is placed into a string or numeric variable. For example, a typical input sequence for an HP controller with BASIC 4.0 is:

```
ENTER 718;CROSSPOINT$
```

In this instance, the complete crosspoint string is placed in the Crosspoint$ variable.

Programming Notes

1. Table 4-10 lists the number of bytes that are transmitted for the various data formats.
2. As the data is transmitted in continuous strings (without carriage returns or line feeds), you must format the data for display or printing legibility.

Programming Example

```
 10 DIM SETUP$[650]          ! Dimension for stand-alone unit
 20 REMOTE 718               ! Set 707 for IEEE-488 communication
 30 OUTPUT 718;''G0U2,1X'' ! Full output, all setup #1 data sent
 40 ENTER 718;SETUP$         ! Get data from 707
 50 PRINT SETUP$[1,9]        ! Print setup number
 60 PRINT SETUP$[10,88]      ! Print setup data row by row
 70 PRINT SETUP$[89,167]
 80 PRINT SETUP$[168,246]
 90 PRINT SETUP$[247,325]
100 PRINT SETUP$[326,404]
110 PRINT SETUP$[405,483]
120 PRINT SETUP$[484,562]
130 PRINT SETUP$[563,641]
140 END
```

Table 4-10. Byte Counts for Data Format

Format	Stand-alone			Master with 4 Slaves		
	Bytes per Talk	Talks per Setup	Total Bytes	Bytes per Talk	Talks per Setup	Total Bytes
G0	641	1	641	3205	1	3205
G1	79 (note 1)	9	641	79 (Note 1)	45	3205
G2	(Note 2)	1	(Note 2)	(Note 2)	1	(Note 2)
G3	(Note 2)	1	(Note 2)	(Note 2)	1	(Note 2)
G4	154	1	154	770	1	770
G5	154	1	154	154	5 (Note 3)	770
G6	76	1	76	380	1	380
G7	76	1	76	76	5 (Note 3)	380

Notes:

1. In addition, each unit is identified with a 9-byte ASCII string.
2. This value depends on the number of closed crosspoints.
3. Maximum of 5 talks, depending on number of slaves in the system.

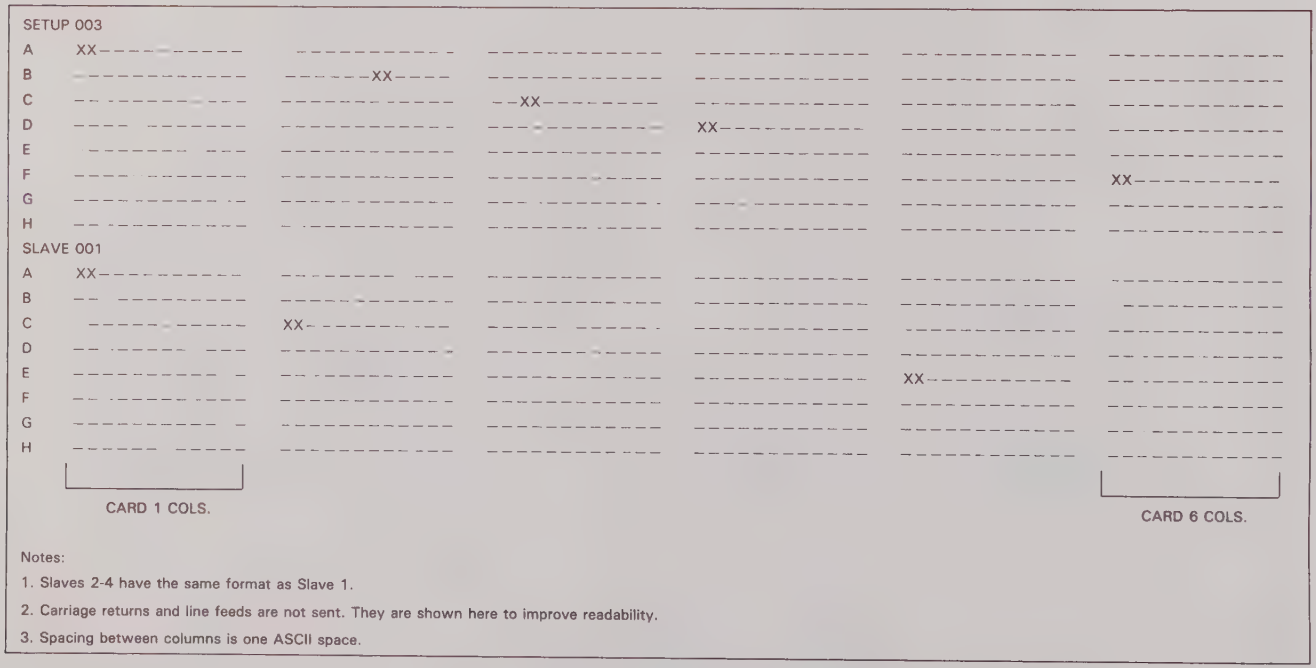

SETUP 003
SLAVE 001
CARD 1 COLS.
CARD 6 COLS.
Notes:
1. Slaves 2-4 have the same format as Slave 1.
2. Carriage returns and line feeds are not sent. They are shown here to improve readability.
3. Spacing between columns is one ASCII space.

Figure 4-8. G0 and G1 Full Output Formats

A001,A002,B019,B020,C027,C028,D037,D038,F061,F062,A073,A074,C085,C086,E121,E122,A187,A188,H205,
H206,A223,A224,H265,H266,G301,G302,A313,A314,H337,H338,E355,E356

Note: Carriage returns and line feeds are not sent. They are shown here to improve readability.

Figure 4-9. G2 and G3 Inspect Output Formats

```
MASTER  0003 00
        010100000000  000000000000   ←CARD 1, COLS. 1-12
        000000000000  020200000000
        000004040000  000000000000
        080800000000  000000000000
        000000000000  000000000000
        202000000000  000000000000   ←CARD 6, COLS. 61-72
        XX

SLAVE 1 0003 01
        010100000000  000000000000
        040400000000  000000000000
        000000000000  000000000000
        000000000000  000000000000
        101000000000  000000000000
        000000000000  000000000000
        XX
```

Notes
1. Slaves 2-4 have the same format as that shown.
2. Carriage returns, line feeds, spaces, and blank lines are not sent. They are shown here to improve readability.
3. "XX" represents a 1-byte checksum value (hexadecimal) in printable ASCII.
4. The rows that correspond to the G4/G5 data are as follows:

G4/G5 Data	Corresponding Row
00	none
01	A
02	B
04	C
08	D
10	E
20	F
40	G
80	H

Figure 4-10. G4 and G5 Condensed Output Formats

```
                                                                ROW H      ROW A
                                                                  ↓          ↓
        ┌ 00000000  00000011  00000000
        │ 00000001  00000001  00000000  00000000  00000000  00000000  ←COLS. 1-6  ┐
        │ 00000000  00000000  00000000  00000000  00000000  00000000  ←COLS. 7-12 ┘ ←CARD 1
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000010  00000010  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000100  00000100  00000000  00000000
MASTER  │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00001000  00001000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00100000  00100000  00000000  00000000  00000000  00000000  ←COLS. 61-66┐
        │ 00000000  00000000  00000000  00000000  00000000  00000000  ←COLS. 67-72┘ ←CARD 6
        └ XXXXXXXX

        ┌ 00000000  00000011  00000001
        │ 00000001  00000001  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000100  00000100  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
SLAVE 1 │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00010000  00010000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        │ 00000000  00000000  00000000  00000000  00000000  00000000
        └ XXXXXXXX
```

Notes

1. Row A corresponds to the least significant bit of each 8-bit group, Row H to the most significant bit.
2. Slaves 2-4 have the same format as that shown.
3. Data is shown as the binary representation of 8-bit binary numbers. The binary value sent may not correspond to a printable ASCII character.
4. Carriage returns, line feeds, spaces, and blank lines are not sent. They are shown here to improve readability.
5. "XXXXXXXX" represents an 8-bit checksum value in binary.

Figure 4-11. G6 and G7 Binary Output Formats

4.9.8 H - Hit Key

Purpose To allow emulation of front panel key press sequence.

Format **Hn**

Parameters The parameter "n" represents the number of the front panel key as shown in the following table.

Command	Key	Command	Key
H1	MEMORY	H22	H
H2	RELAYS	H23	F
H3	COPY DISPLAY→MEMORY	H24	D
H4	COPY DISPLAY→RELAYS	H25	B
H5	AUTOMATIC	H26	7
H6	SCROLL ▲	H27	4
H7	SCROLL ▼	H28	1
H8	INSERT	H29	0
H9	DELETE	H30	8
H10	MENU	H31	5
H11	SETTLING TIME	H32	2
H12	MAKE/BREAK	H33	CANCEL
H13	BREAK/MAKE	H34	9
H14	LOCAL	H35	6
H15	ENABLE	H36	3
H16	SOURCE	H37	ENTER
H17	MANUAL	H38	RESET
H18	G	H39	CLEAR
H19	E	H40	OPEN
H20	C	H41	CLOSE
H21	A		

Description The H command and its options allow you to emulate front panel keystroke sequences. To emulate any such sequence, simply send the appropriate commands in the necessary order.

Programming Notes
1. The X character must follow each command in a multiple command string.
2. The H command is functional even if LLO (Local Lockout) is in effect.

Programming Examples

```
10 OUTPUT 718;''H5X''                    ! Emulate AUTOMATIC key press

10 ! CHANGE PRIMARY ADDRESS OVER
   BUS
20 REMOTE 718                            !
30 CLEAR 718                             !
40 OUTPUT 718;''H10XH10XH10XH10          ! Menu option for IEEE-488 address
   XH10X''
50 OUTPUT 718;''H32XH29XH37X''           ! Set address to 20
60 WAIT .2                               ! Delay 0.2sec
70 REMOTE 720                            !
80 CLEAR 720                             !
90 ENTER 720;A$                          ! Test communication to device 20
100 PRINT A$                             ! by requesting software revision
110 END
```

4.9.9 I - Insert Blank Setup

Purpose To insert a blank setup in memory.

Format **In**

Parameters n = 1 to 100 Stored relay setup

Description During execution of this command, setups ''n'' through 99 are shifted up to the next higher location in memory (99 to 100, 98 to 99 ... n to n+1). Then, all cross-points of setup ''n'' are cleared. The front panel display is blanked during an insert operation.

Programming Note This command is equivalent to a single or multiple front panel key press(es).

Programming Example

```
10 OUTPUT 718;''I50X''    ! Insert blank setup at location 50
```

4.9.10 J - Self-test

Purpose To test ROM, RAM, and the front panel display segments.

Format **Jn**

Parameters J0 = Perform self-test

Description The self-test command starts execution of the ROM, RAM, and display tests. If an error is detected in ROM or RAM, a ''ROM FAIL'' or ''RAM FAIL'' message is displayed. Any front panel keypress or bus command overrides the message display. The display test lights all segments of the alphanumeric display for your inspection.

Programming Notes

1. The value ''n'', if sent, must be zero.
2. Allow approximately four seconds for the instrument to complete the self-test.
3. The instrument holds off bus operation with the NRFD line during self-test operation. Thus, no commands can be sent during the self-test if hold-off on X is enabled.
4. This command is equivalent to a front panel menu selection.

Programming Example

```
10 OUTPUT 718;''J0X''  ! Perform self-test
```

4.9.11 K - EOI and Hold-off

Purpose To enable/disable EOI and bus hold-off on X.

Format **Kn**

Parameters
K0 = Send EOI with last byte, hold-off on X until Ready
K1 = No EOI, hold-off on X until Ready
K2 = Send EOI with last byte, do not hold-off on X
K3 = No EOI, do not hold-off on X
K4 = Send EOI with last byte, hold-off on X until Matrix Ready
K5 = No EOI, hold-off on X until Matrix Ready

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to K0 (send EOI with last byte, hold-off on X until ready).

Description The EOI line provides one method to positively identify the last byte in the data string sent by the instrument. When enabled, EOI is asserted with the last byte the instrument sends over the bus.

Bus hold-off allows the instrument to temporarily hold up bus operation via the NRFD line when it receives the X character until all commands are processed. The advantage of using bus hold-off is that no commands are missed while the instrument is processing previously received commands. Typical hold-off times are discussed in paragraph 4.10.

Programming Notes
1. Some controllers rely on EOI to terminate their input sequences. Suppressing EOI may cause the controller input sequence to hang.
2. When reading a buffer, EOI is asserted only at the end of the entire buffer transmission.
3. When enabled, EOI is asserted with the last byte in the terminator.
4. When bus hold-off is enabled, all bus activity is held up for the duration of the hold-off period — not just communication with the Model 707.

Programming Example

```
10 OUTPUT 718;"K1X"  ! No EOI, hold-off on X until Ready
20 OUTPUT 718;"K2X"  ! Send EOI with last byte, do not hold-off on X
```

4.9.12 L - Download Setups

Purpose To download setups from the controller to the Model 707.

Format **Lbbbb...X**

Parameters bbbb... represents the G4/G5 or G6/G7 output string.

Description This command downloads setup information in a G4/G5 or G6/G7 data format. It is used in conjunction with the U2 command (output setup data) to back up or expand the setups stored in the Model 707.

G formats are discussed in paragraph 4.9.7; see paragraph 4.9.21 for U commands.

Programming Notes

1. The data format for downloading is specified by the G format currently in effect.
2. The setup data string begins with a setup number and unit number and ends with a checksum value.
3. The setup number is specified in a U2,n command (output setup ''n''), as shown in the following programming example.

Programming Example

```
10  DIM SETUP$[200]          ! Dimension for stand-alone
20  REMOTE 718
30  OUTPUT 718;''G4U2,1X'' ! Setup #1 in G4 format
40  ENTER 718;SETUP$         ! Get setup data
50  PRINT SETUP$[1,6]        ! Print setup and unit numbers
60  PRINT SETUP$[7,30]       ! Print setup data card by card
70  PRINT SETUP$[31,54]
80  PRINT SETUP$[55,78]
90  PRINT SETUP$[79,102]
100 PRINT SETUP$[103,126]
110 PRINT SETUP$[127,150]
120 PRINT SETUP$[151,152]  ! Print checksum
130 PRINT ''PRESS CONTINUE  ! Inspect setup data
    TO DOWNLOAD''
140 PAUSE                    ! Wait for controller's CONTINUE key
150 OUTPUT 718;''L''&SETUP ! Download setup back to 707
    $&''X''
160 END
```

4.9.13 M - SRQ and Serial Poll Byte

Purpose To program which conditions generate an SRQ (service request).

Format **Mn**

Parameters
M0 = SRQ disabled
M1 = not used
M2 = Front panel key press
M4 = Digital I/O interrupt
M8 = Matrix Ready
M16 = Ready for trigger
M32 = Error
M128 = not used

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to M0 (SRQ disabled).

Description The SRQ command selects which conditions cause the Model 707 to generate an SRQ (service request). Once an SRQ is generated, the serial poll byte can be checked to determine if the Model 707 was the instrument that generated the SRQ, and, if so, what conditions caused it.

The general format of the SRQ mask used to generate SRQs is shown in Figure 4-12. By sending the appropriate M command, you can set the appropriate bit or bits to enable SRQ generation if those particular conditions occur. Possible conditions include:

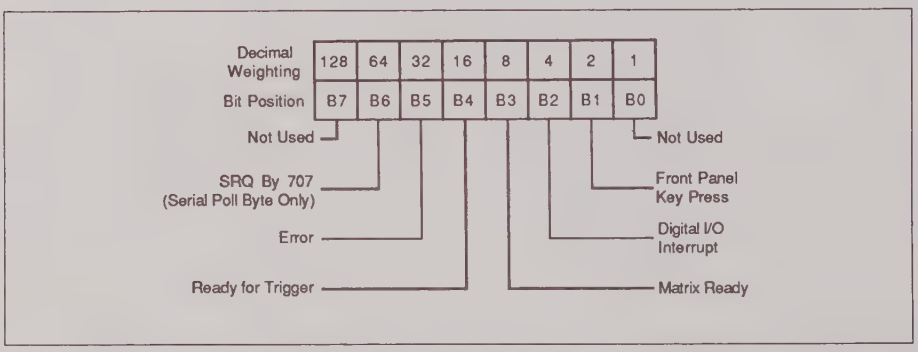


Figure 4-12. SRQ Mask and Serial Poll Byte Format

- A front panel key has been pressed (M2).
- An interrupt condition has been received at the Digital I/O port (M4).
- The Matrix Ready signal has been asserted (M8).
- The Ready (for trigger) signal has been asserted (M16).
- An error has occurred (M32). The nature of the error can be determined by reading the U1 error word as described in paragraph 4.9.21.

Serial Poll Byte

The general format of the serial poll byte is shown in Figure 4-12. Note that all bits except for bit 6 correspond to the bits in the SRQ mask. These bits flag the following conditions:

Front Panel Key Press (bit 1)—Set when the Model 707 detects a key press, including keys "pressed" with the H command. It is cleared by reading U0 machine status word (see paragraph 4.9.21).

Digital I/O Interrupt (bit 2)—Set when the INLATCH signal of the digital I/O port is brought low to latch in the present states of the digital inputs. (Further changes to the inputs of the digital I/O port are ignored until the latched data is read.) Cleared by reading the master unit's digital input with the U7 command (see paragraph 4.9.21).

NOTE

It is not necessary to read the digital input value every time INLATCH causes an SRQ to be generated. The INLATCH signal can be used to indicate a user-defined interrupt condition, with multiple assertions causing multiple interrupts.

Matrix Ready (bit 3)—Set whenever the Matrix Ready signal is asserted. Cleared by the start of relay switching.

Ready for Trigger (bit 4)—Set whenever the Ready signal is asserted. This bit is cleared by:

- Receipt of X.
- Start of relay switching.
- Front panel key press on master unit.
- Changing Make/Break or Break/Make row.
- Performing self-test.
- Pressing RELAYS key.

NOTE

Using the H command to "hit" keys could cause the Ready bit to cycle twice: once when the H command is processed and again when the key press is processed.

Error (bit 5)—Set if an error condition occurs. Cleared by reading the U1 error status word (paragraph 4.9.21).

SRQ (bit 6)—Set if the Model 707 requests service via the SRQ line; cleared by a serial poll.

Programming Notes

1. The serial poll byte should be read once the instrument has generated an SRQ to clear the SRQ line.
2. All bits in the serial poll byte latch when the instrument generates an SRQ.
3. If an error occurs, bit 5 (error) in the serial poll byte latches and remains so until the U1 word is read (paragraph 4.9.21).
4. Multiple error conditions can be programmed by adding up the individual command values. For example, send M12X for SRQ under matrix ready and digital I/O interrupt conditions.

Programming Example

```
 10 CLEAR 718
 20 REMOTE 718
 30 OUTPUT 718;''M32X''          ! Program for SRQ on error
 40 OUTPUT 718;''A2X''           ! Attempt to program invalid
                                   option
 50 STATUS 7,2;S                 ! Check interface status
 60 IF NOT BIT(S,5) THEN 50      ! Wait for SRQ to occur
 70 S=SPOLL(718)                 ! Serial poll the instrument
 80 PRINT ''B7 B6 B5 B4 B3 B2 B1 B0''  ! Label the bit positions
 90 FOR I=7 TO 0 STEP-1          ! Loop eight times
100 PRINT BIT(S,I);              ! Display the bit positions
110 NEXT I
120 PRINT
130 OUTPUT 718;''U1X''           ! Program for error status
140 ENTER 718;ERROR$             ! Get U1 status to clear error
150 PRINT ERROR$                 ! Display error status
160 END
```

Serial Poll Byte

The general format of the serial poll byte is shown in Figure 4-12. Note that all bits except for bit 6 correspond to the bits in the SRQ mask. These bits flag the following conditions:

Front Panel Key Press (bit 1)—Set when the Model 707 detects a key press, including keys "pressed" with the H command. It is cleared by reading U0 machine status word (see paragraph 4.9.21).

Digital I/O Interrupt (bit 2)—Set when the INLATCH signal of the digital I/O port is brought low to latch in the present states of the digital inputs. (Further changes to the inputs of the digital I/O port are ignored until the latched data is read.) Cleared by reading the master unit's digital input with the U7 command (see paragraph 4.9.21).

Matrix Ready (bit 3)—Set whenever the Matrix Ready signal is asserted. Cleared by the start of relay switching.

Ready for Trigger (bit 4)—Set whenever the Ready signal is asserted. This bit is cleared by:

- Receipt of X.
- Start of relay switching.
- Front panel key press on master unit.
- Changing Make/Break or Break/Make row.
- Performing self-test.
- Pressing RELAYS key.

NOTE

Using the H command to "hit" keys could cause the Ready bit to cycle twice: once when the H command is processed and again when the key press is processed.

Error (bit 5)—Set if an error condition occurs. Cleared by reading the U1 error status word (paragraph 4.9.21).

SRQ (bit 6)—Set if the Model 707 requests service via the SRQ line; cleared by a serial poll.

Programming Notes

1. The serial poll byte should be read once the instrument has generated an SRQ to clear the SRQ line.
2. All bits in the serial poll byte latch when the instrument generates an SRQ.
3. If an error occurs, bit 5 (error) in the serial poll byte latches and remains so until the U1 word is read (paragraph 4.9.21).
4. Multiple error conditions can be programmed by adding up the individual command values. For example, send M12X for SRQ under matrix ready and digital I/O interrupt conditions.

Programming Example

```
 10 CLEAR 718
 20 REMOTE 718
 30 OUTPUT 718;''M32X''              ! Program for SRQ on error
 40 OUTPUT 718;''A2X''               ! Attempt to program invalid
                                       option
 50 STATUS 7,2;S                     ! Check interface status
 60 IF NOT BIT(S,5) THEN 50          ! Wait for SRQ to occur
 70 S=SPOLL(718)                     ! Serial poll the instrument
 80 PRINT ''B7 B6 B5 B4 B3 B2 B1 B0'' ! Label the bit positions
 90 FOR I=7 TO 0 STEP-1              ! Loop eight times
100 PRINT BIT(S,I);                  ! Display the bit positions
110 NEXT I
120 PRINT
130 OUTPUT 718;''U1X''               ! Program for error status
140 ENTER 718;ERROR$                 ! Get U1 status to clear error
150 PRINT ERROR$                     ! Display error status
160 END
```

4.9.14 N - Open Crosspoint

Purpose To open crosspoints in a setup.

Format **Nrc(,rc)...(,rc)**

Parameters
r = Row A to row H
c = Column 1 to column 360

Description The N command opens crosspoints in the setup indicated by the edit pointer. If the edit pointer indicates the current relay setup (zero), the specified crosspoint relays are opened immediately. If the edit pointer indicates a setup stored in memory (1-100), the specified crosspoints are cleared.

Programming Notes
1. Do not include parentheses in command strings. They indicate that the option and associated comma delimiter are optional.
2. Up to 25 crosspoints per mainframe can be specified in one open command (with a master and four slaves, the limit is 125 crosspoints). In the same command string, up to 25 crosspoints per mainframe can be closed. If either limit is exceeded, an IDDCO results.
3. The maximum value of the column parameter depends on the configuration (72 for stand-alone, 360 for master with four slave units). An IDDCO results if the maximum value is exceeded.
4. This command is equivalent to multiple front panel key presses or light pen operation(s).

Programming Example

```
10 OUTPUT 718;''NA55X''                    ! Open one crosspoint
20 OUTPUT 718;''NA55,A56,B49,B50X''        ! Open multiple crosspoints
```

4.9.15 O - Digital Output

Purpose To set the states of the digital output lines.

Format **Ovvv**

Parameters vvv = 000 to 255 (Decimal value of digital output)

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to O000 (all digital outputs set to logic low).

Description This command is a decimal representation of the states of individual output lines of the Digital I/O port, where ''1'' is logic high and ''0'' is logic low. Bit assignments and corresponding connector pins are shown below:

Bit Position	7	6	5	4	3	2	1	0
Bit Weight	128	64	32	16	8	4	2	1
Digital Output Pin	24	23	22	21	20	19	18	17

Programming Notes

1. In a master/slave configuration, only the output of the master unit is updated.
2. Leading zeros are not necessary in the parameter value.
3. The OUTPULSE signal on the digital I/O port is brought low when this command is executed, even if the output states are not changed.
4. This command is equivalent to a front panel menu selection.

Programming Example

```
10 OUTPUT 718;''O15X''  ! Set bits <3-0> high
20 OUTPUT 718;''O0X''   ! Restore default condition
```

4.9.16 P - Clear Crosspoints

Purpose To clear all crosspoints at the specified setup.

Format **Pn**

Parameters n = 0 Current relay setup
n = 1 to 100 Stored relay setup

Description The P command clears all crosspoints in the setup indicated by its parameter. If the current relay setup (zero) is specified, all crosspoint relays are opened immediately. If setup stored in memory (1-100) is specified, all crosspoints of that setup are cleared.

Programming Note This command is equivalent to multiple front panel key presses.

Programming Example

```
10 OUTPUT 718;''P0X''    ! Open all relays
20 OUTPUT 718;''P20X''   ! Clear setup #20
```

4.9.17 Q - Delete Setup

Purpose To delete a setup from memory.

Format **Qn**

Parameters n = 1 to 100 Stored relay setup

Description During execution of this command, setups ''n+1'' through 100 are shifted down to the next lower location in memory (''n+1'' to ''n'' ... 100 to 99). Then, all crosspoints of setup #100 are cleared. The front panel display is blanked during a delete operation.

Programming Notes
1. The command Q100 clears all crosspoints of setup #100.
2. This command is equivalent to a single or multiple front panel key press(es).

Programming Example

```
10 OUTPUT 718;''Q50X''  ! Delete setup #50 from memory
```

4.9.18 R - Restore Defaults

Purpose To restore the Model 707 to factory default conditions.

Format **Rn**

Parameters R0 = Restore factory defaults

Description An R0 command performs the following actions:

- All setups stored in memory are cleared.
- Make/Break and Break/Make rows are cleared.
- A Device Clear operation (all crosspoint relays are opened, RELAY STEP pointer is set to 000, MEMORY STEP is set to 001).

DDC parameters are set to the values shown below:

A0	Initiate trigger on falling edge of External Trigger pulse.
B0	Set Matrix Ready output signal to negative true.
DX	Set normal operation for alphanumeric display.
E000	Set edit pointer to current relay setup.
F0	Disable triggers.
G0	Set full output format, all data sent in one talk.
K0	Send EOI with last byte, hold-off on X until ready.
M000	Disable all SRQ sources.
O000	Set all digital outputs to logic low.
S00000	Set user settling time to zero.
T7	Trigger Model 707 on external trigger pulse.
V00000000	De-select all rows for make/break.
W00000000	De-select all rows for break/make.
Y0	Set terminator characters of <CR><LF>.

Programming Notes

1. The primary IEEE-488 address and master/slave operation are not affected by the Restore command.
2. This command is equivalent to a front panel menu selection.

Programming Example

```
10 OUTPUT 718;"R0X"  ! Restore default conditions, clear setups
```

4.9.19 S - Programmed Settling Time

Purpose To program the settling time.

Format **Sn**

Parameters n = 0 to 65000 Time in msec

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to S0 (programmed settling time of zero).

Description With the S command, you can program the settling time (up to 65 seconds). The programmed settling time starts after the longest relay settling time has elapsed.

Programming Notes

1. This command is equivalent to multiple front panel key presses.
2. The total settling time equals the longest relay settling time of any card in the system plus any user-programmed settling time. Figure 4-13 shows a timing diagram of the settling times. Additional timing diagrams are given in paragraph 3.11.

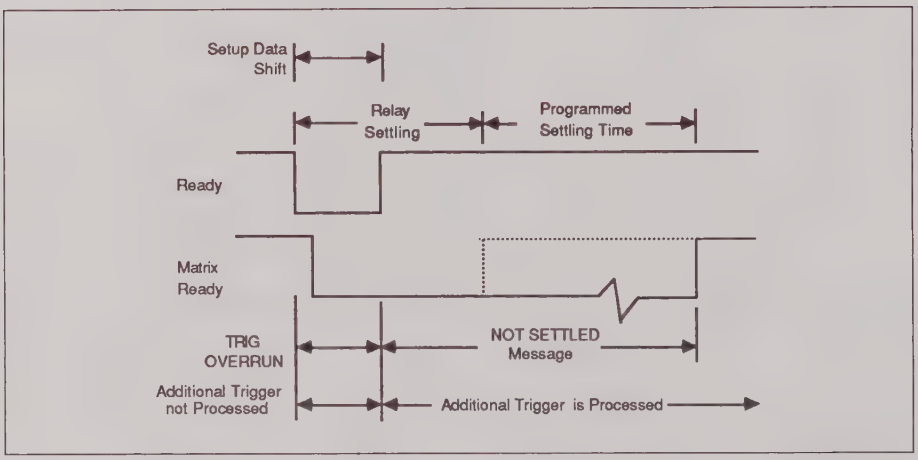


Figure 4-13. READY and MATRIX READY Signal Timing

Programming Examples

```
10 OUTPUT 718;''S5000X''   ! Program 5sec settling time
20 OUTPUT 718;''S0X''      ! Restore default conditon
```

4.9.20 T - Trigger

Purpose To select the trigger source.

Format **Tn**

Parameters
T0 or T1 = Trigger on talk
T2 or T3 = Trigger on GET
T4 or T5 = Trigger on X
T6 or T7 = Trigger on External Trigger pulse
T8 or T9 = Trigger on front panel MANUAL key

Default Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to T7 (trigger on external trigger pulse).

Description With the trigger command, you can determine the trigger source: over the bus, from an external trigger pulse, or from the front panel. A valid trigger increments the RELAY STEP pointer by one, stopping at 100, and copies the setup data indicated by the new value to the relays.

Programming Notes
1. Duplication of trigger sources allows compatibility with other Keithley IEEE-488 instruction sets.
2. It is good programming practice to disable triggers before changing the trigger source.
3. If the unit is re-triggered while it is still processing a previous trigger, it displays either a TRIG OVERRUN or NOT SETTLED message, depending on when the additional trigger occurs. The timing diagrams are shown in paragraph 3.11.
4. To trigger the instrument when using the trigger on talk, you must send the talk command derived from the correct primary address. The factory default primary address is 18. Trigger on talk does not occur when the Model 707 becomes a talker, but rather as the controller requests the first byte of data from the unit.
5. Trigger on GET allows the fastest IEEE-488 triggering response.
6. The X character that is sent when programming a trigger on X source triggers the instrument.
7. Front panel triggering with the MANUAL key is always enabled regardless of the programmed trigger source (while the TRIGGER ENABLE LED is lit); however, all front panel keys are locked out if the unit is in remote (REMOTE on). To restore local operation in this case, press the LOCAL key.
8. This command is equivalent to multiple front panel key presses.

Programming Examples

```
10 OUTPUT 718;''F0T0X''  ! Disable triggers, program trigger on talk.
20 OUTPUT 718;''F1X''    ! Enable triggers
30 ENTER 718;A$          ! Trigger next setup

10 OUTPUT 718;''F0T2X''  ! Disable triggers, program trigger on GET
20 OUTPUT 718;''F1X''    ! Enable triggers
30 TRIGGER 718           ! Trigger next setup
```

4.9.21 U - Status

Purpose To obtain instrument status and system configuration.

Format **Un**

Parameters
U0 = Send machine status word.
U1 = Send error status word.
U2,n = Output setup "n" (0-100) with current G format.
U3 = Send value of RELAY STEP pointer.
U4 = Send number of slaves.
U5,u = Send ID of each card in unit "u" (0-4).
U6 = Send longest relay settling time.
U7 = Send digital input of unit.
U8 = Send RELAY TEST input.

Description By sending the appropriate U command and then addressing the instrument to talk as with normal data, you can obtain information on machine status, error conditions, and other data.

U0 Machine Status Word

The format of U0 is shown in Figure 4-14. The letters correspond to modes programmed by the respective device-dependent commands. Returned values correspond to the programmed numeric values. The values shown in Figure 4-14 are the default values. (Note that the value for "H" is the last key hit, even after an R0 command or power cycle.)

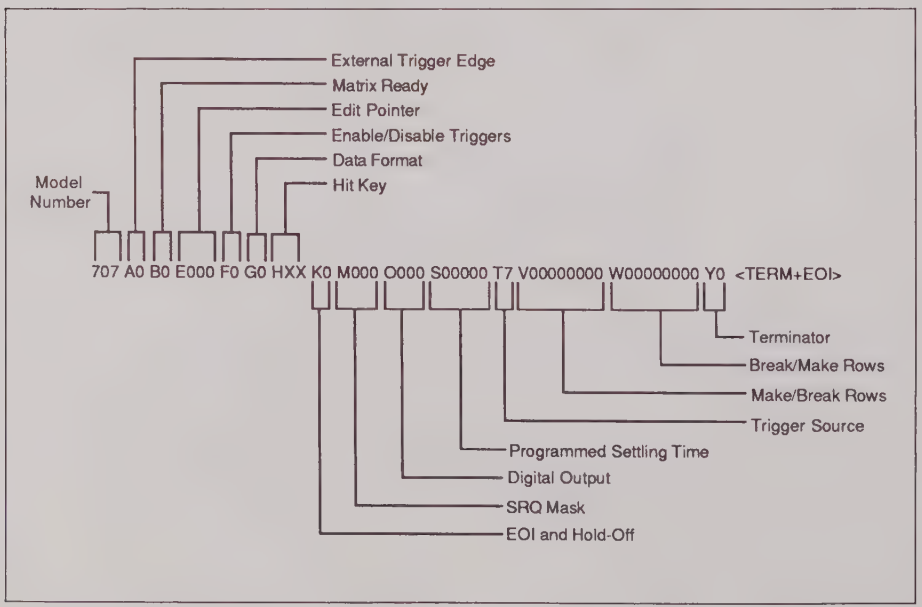


Figure 4-14. U0 Machine Status Word

U1 Error Status Word

The U1 command allows access to Model 707 error conditions. The error status word (Figure 4-15) is actually a string of ASCII characters representing binary bit positions. Reading the U1 status clears the error bits. An error condition is flagged in the serial poll byte while any bits in the error status word are set. The instrument can be programmed to generate an SRQ when an error condition occurs (see paragraph 4.9.13).

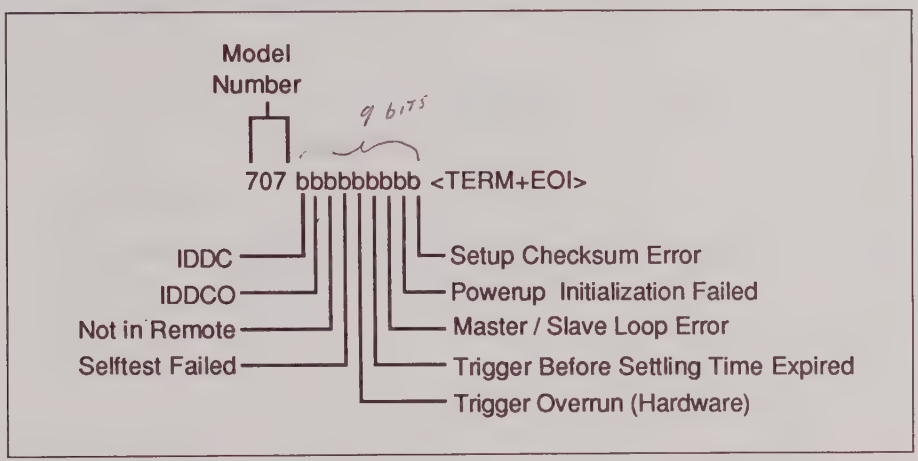


Figure 4-15. U1 Error Status Word

The various bits in the U1 error status word are set when the following conditions are present:

IDDC—An invalid device-dependent command (IDDC) is received.

IDDCO—An invalid device-dependent command option (IDDCO) is received.

Not in Remote—An X command is received over the bus but the Model 707 is not in remote.

Self-test Failed—The self-test detects a program ROM checksum error or a RAM error.

Trigger Overrun (Hardware)—A trigger is received before the Ready signal is asserted. The trigger is ignored.

Trigger Before Settling Time Expired—A trigger is received before the Matrix Ready signal is asserted. The trigger is processed.

Master/Slave Loop Error—There is a communication or timing error in the master/slave loop.

Power-up Initialization Failed—The power-up routine has detected a checksum error in the information from one or more matrix cards.

Setup Checksum Error—The power-up routine detects a checksum error in one or more setups stored in memory. (The affected setups are cleared.)

U2,n Formatted Setup

With the U2 command, you can request the Model 707 to output data of either the current relay setup (n=0) or a stored setup (1<=n<=100) according to the G format presently in effect. (See paragraph 4.9.7.)

U3 RELAY STEP pointer

The U3 command (Figure 4-16) requests the value of the RELAY STEP pointer, which indicates the last setup sent to the relays (000<=nnn<=100).

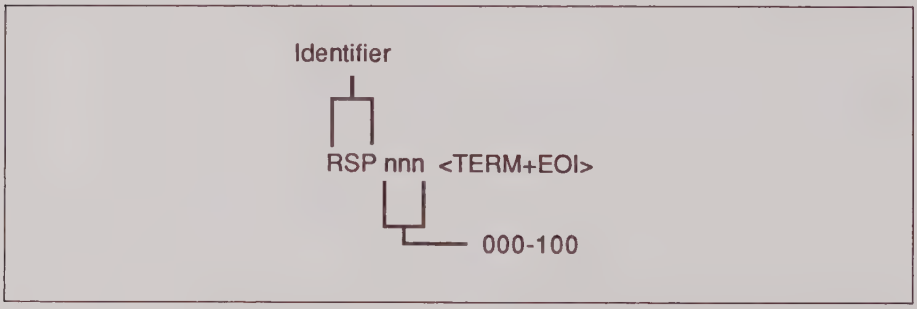


Figure 4-16. U3 Relay Step Pointer

U4 Number of slaves

With the U4 command (Figure 4-17), you can request the number of slaves present in a master/slave loop configuration (between 1 and 4).

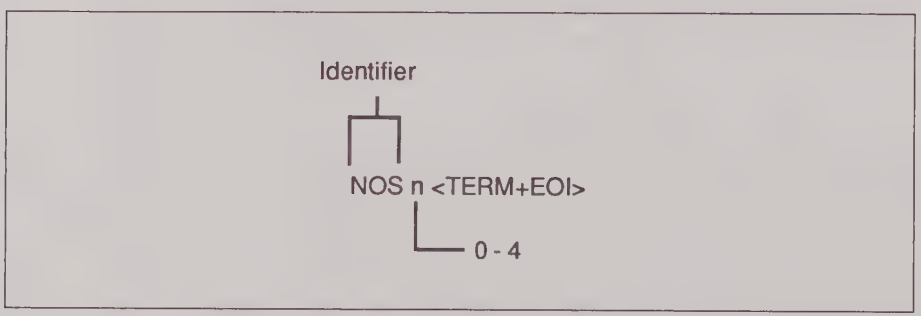


Figure 4-17. U4 Number of Slaves

U5,u Card IDs

By specifying a unit number in the U5 command (0 for master, 1-4 for slaves), you can request the model numbers of the cards present in each mainframe. The output format is shown in Figure 4-18. The character string for an empty slot is ''NONE''. This command is equivalent to a front panel menu selection.

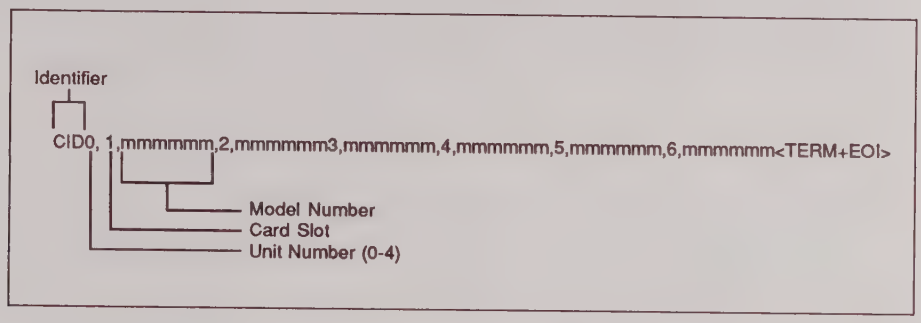


Figure 4-18. U5 Card Identifications

U6 Relay settling time

The U6 command (Figure 4-19) requests the Model 707 to output the longest relay settling time of all cards in the system (expressed in msec). This command is equivalent to a front panel menu selection.

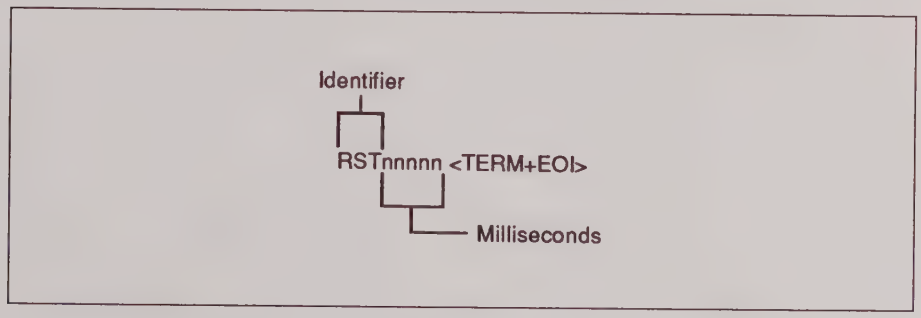


Figure 4-19. U6 Relay Settling Time

U7 Digital input

The U7 command (Figure 4-20) requests a decimal value of the inputs at the Digital I/O port. If bit 2 of the serial poll byte is set, the previously latched status is sent. If bit 2 of the serial poll byte is cleared, the present states of the digital inputs are read and sent. This command is equivalent to a front panel menu selection.

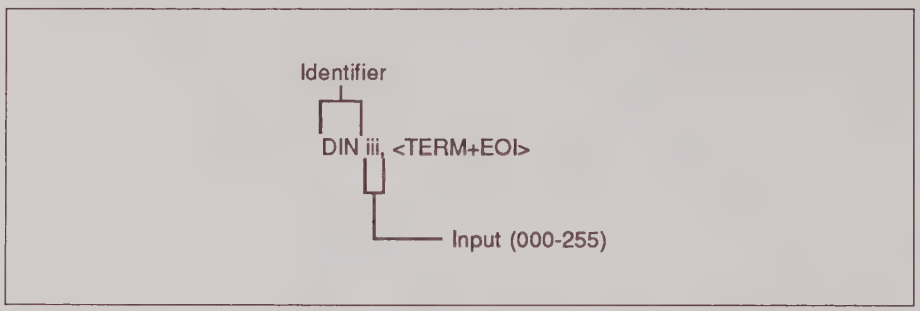


Figure 4-20. U7 Digital Input

In master/slave configurations, the digital input of the master unit is sent.

U8 Relay Test input

The U8 command (Figure 4-21) requests the status of the input pins at the Relay Test connector. Values between 0 and 15 represent the states of pins 1 (LSB) through 4 (MSB).

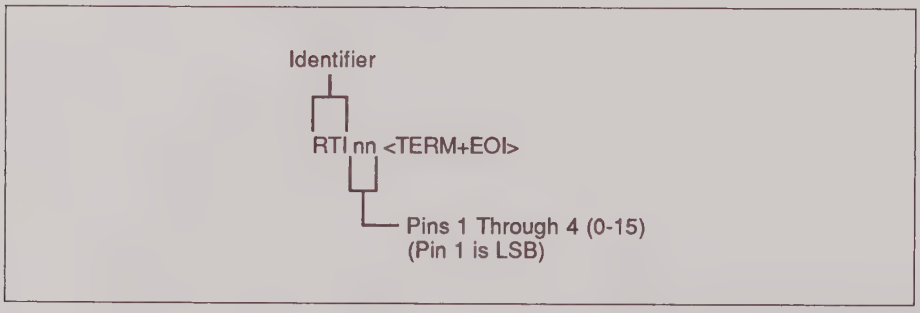


Figure 4-21. U8 Relay Test Input

Programming Notes

1. The instrument transmits the appropriate status word only once each time the corresponding U command is received.
2. To ensure that correct status is indicated, the status word should be requested immediately after the command is transmitted. The status sent by the Model 707 is that which is present at the time it is instructed to talk, not at the time the U command is received.
3. The bits in the U1 error status word latch and remain in that condition until the U1 word is read.
4. The programmed terminator (default CR LF) is transmitted at the end of each status word. Also, EOI is transmitted at the end (unless disabled with the K command).

5. If no U command has been received, an ENTER 718;A$ command requests the letter (x) and number (nn) of the software revision for a stand-alone unit or the master unit of a master/slave configuration (707xnn). It is sent with two trailing spaces plus the terminator and EOI.

Programming Examples

```
10 DIM COMMAND$[50],STATUS$[650]          ! Dimension command and
                                            status.
20 REMOTE 718
30 INPUT ''ENTER U COMMAND'',COMMAND$     ! Get desired U command
40 IF LEN(COMMAND$)=0 THEN 100            ! Check for null
50 OUTPUT 718;COMMAND$&''X''              ! Program 707 with U
                                            command
60 ENTER 718;STATUS$                      ! Get status
70 PRINT STATUS$                          ! Print status
80 PRINT CHR$(128)                        ! Print blank line
90 GOTO 30                                ! Return for next U
                                            command
100 END
```

4.9.22 V - Make/Break

Purpose To select rows for make/break operation.

Format **Vabcdefgh**

Parameters abcdefgh = 00000000 All rows de-selected for make/break
to
11111111 All rows selected for make/break

Description The V command selects individual rows for make/break (make-before-break) operation. A "1" in the respective row field selects make/break; a "0" de-selects make/break operation.

Programming Notes

1. Specifying fewer than eight numbers in the parameter field (e.g. V1111) is invalid. The Model 707 takes no action on the rows and flags an IDDCO error.
2. The rows can be programmed for one of three switching options: make/break, break/make, or don't care. A row cannot be selected for both make/break and break/make at the same time. Selecting it for one de-selects it for the other.
3. This command is equivalent to multiple front panel key presses or light pen operation(s).
4. Given the present states and actions performed, the next states of the rows are listed below:

Present State	Action	Next State
Don't Care	Select Make/Break	Make/Break
	De-select Make/Break	Don't Care
Make/Break	Select Make/Break	Make/Break
	De-select Make/Break	Don't Care
Break/Make	Select Make/Break	Make/Break
	De-select Make/Break	Break/Make

Programming Examples

```
10 OUTPUT 718;"V11110000X"  ! Select rows ABCD for make/break
20 OUTPUT 718;"V00000000X"  ! Restore default condition
```

4.9.23 W - Break/Make

Purpose To select rows for break/make operation.

Format **Wabcdefgh**

Parameters abcdefgh = 00000000 All rows de-selected for break/make
to
11111111 All rows selected for break/make

Description The W command selects individual rows for break/make (break-before-make) operation. A "1" in the respective row field selects break/make; a "0" de-selects break/make operation.

Programming Notes

1. Specifying fewer than 8 numbers in the parameter field (e.g. W1111) is invalid. The Model 707 takes no action on the rows and flags an IDDCO error.
2. The rows can be programmed for one of three switching options: make/break, break/make, or don't care. A row cannot be selected for both make/break and break/make at the same time. Selecting it for one de-selects it for the other.
3. This command is equivalent to multiple front panel key presses or light pen operation(s).
4. Given the present states and actions performed, the next states of the rows are listed below:

Present State	Action	Next State
Don't Care	Select Break/Make	Break/Make
	De-select Break/Make	Don't Care
Make/Break	Select Break/Make	Break/Make
	De-select Break/Make	Make/Break
Break/Make	Select Break/Make	Break/Make
	De-select Break/Make	Don't Care

Programming Examples

```
10 OUTPUT 718;''W11110000X''  ! Select rows ABCD for break/make
20 OUTPUT 718;''W00000000X''  ! Restore default condition
```

4.9.24 X - Execute

Purpose To direct the Model 707 to execute device-dependent commands received since last X.

Format <command>X

Parameters None

Description The execute command is implemented by sending an ASCII X over the bus. Its purpose is to direct the Model 707 to execute other device-dependent commands. Generally, the execute character is the last byte sent in the command string; however, there may be some cases when it is desirable to send a string of charcters at one time and then send the execute character later on.

Programming Notes

1. Commands or command strings sent without the X character are not executed at that time, but they are stored in an internal command buffer for later execution once the X character is finally received.
2. The X character can also be used to trigger, as described in paragraph 4.9.20.
3. Commands are not necessarily executed in the order sent (see Table 4-7). To force a particular command sequence, include the X character after each command in the command string.

Programming Examples

```
10 OUTPUT 718;''E1X''          ! Execute single command
20 OUTPUT 718;''E1CA47X''      ! Execute multiple commands
30 OUTPUT 718;''T6XA1XR1X''    ! Force command sequence
40 OUTPUT 718;''G2Y1''         ! Send string without execute
50 OUTPUT 718;''X''            ! Now execute command string at later
                                 time
```

4.9.25 Y - Terminator

Purpose

To select the ASCII terminator sequence that marks the end of the instrument's data string or status word.

Format

Yn

Parameters

Y0 <CR><LF>
Y1 <LF><CR>
Y2 <CR>
Y3 <LF>

Default

Upon power-up, or after receiving a DCL, SDC, or R0X command, the instrument defaults to Y0 (<CR><LF>).

Description

By using the Y command, you can program the number and type of terminator characters the instrument sends at the end of its data string. Available terminator characters are the commonly used CR (carriage return, ASCII 13) and LF (line feed, ASCII 10) characters. These terminator characters are recognized by most controllers.

Programming Notes

1. EOI is another method that can be used to terminate the controller input sequence, as discussed in paragraph 4.9.11. EOI is asserted with the last terminator byte when enabled.
2. The programmed terminator is sent at the end of the transmission each time the Model 707 is addressed to talk, regardless of the selected data format.
3. Status word programming is covered in paragraph 4.9.21.

Programming Examples

```
10 OUTPUT 718;"Y2X"  ! Program CR only as terminator
20 OUTPUT 718;"Y3X"  ! Terminate on LF
30 OUTPUT 718;"Y0X"  ! Restore default terminator
```

4.9.26 Z - Copy Setup

Purpose To copy a setup from relays or memory to relays or memory.

Format **Zm,n**

Parameters
0,n = Current relay setup to stored setup "n" (1-100)
n,0 = Stored setup "n" (1-100) to current relay setup
m,n = Setup "m" (0-100) to setup "n" (0-100)

Description By specifying a source and destination in the Z command, you can copy data between stored setups and between the relays and setups stored in memory. Copying a setup to the relays sets the RELAY STEP pointer to that setup.

Programming Notes
1. The command "Z0,0X" sends the current relay setup to the relays. There is no effect on the relays. The command merely resets the RELAY STEP pointer to 000.
2. This command is equivalent to multiple front panel key presses.

Programming Examples

```
10 OUTPUT 718;''Z0,10X''   ! Copy current relay setup to setup 10
20 OUTPUT 718;''Z20,0X''   ! Copy setup 20 from memory to relays
30 OUTPUT 718;''Z10,20X''  ! Copy setup 10 to setup 20
```

4.10 RELAY COMMAND COMBINATIONS

There are four device-dependent commands that have an immediate effect on relay states:

- E0N... - Point to relays, open specified crosspoints.
- E0C... - Point to relays, close specified crosspoints.
- P0 - Open all relays.
- Zn,0 - Copy setup "n" to relays.

Combinations of these commands in the same command string cause only one relay switching operation when the X character is received. The command hierarchy (E, P, Z, N, C) determines the final data that is sent to the relays. This is shown in the following examples.

Example 1

The command string "E0P0CA1X" sets the edit pointer to the current relay setup, opens all relays, and closes crosspoint A1. A1 will be the only closed crosspoint.

Example 2

The string "E0Z5,0CA1X" sets the edit pointer to the relays, copies stored setup #5 to the relays, and closes crosspoint A1. A1 will be closed regardless of the state of A1 in setup #5. The status of the relays will be a combination of setup #5 and a closed A1 crosspoint.

Example 3

The command string "E0Z5,0NA1X" points to the relays, copies setup #5 to the relays, and opens crosspoint A1. If setup #5 had specified A1 to be closed, the command NA1 overrides that. (A1 will not close, then open, as there will be only one relay switching operation.) The relays will reflect setup #5 and an open A1 crosspoint.

4.11 TIMING CONSIDERATIONS

Timing considerations for IEEE-488 programming include:

- Data transfer rates between the controller and Model 707 (stand-alone or master) over the IEEE-488 bus.
- Command string parse time within the stand-alone or master unit.
- Data transfer rates among the units in a master/slave loop.
- Execution times of the tasks defined by device-dependent commands.

The times needed for these actions are determined by the length of the command string, the number of units in a master/slave configuration, the types of commands, and the speed of the controller.

Typically, a command string sent to the Model 707 will transmit at a rate of four characters per millisecond. (Assuming the transfer speed of the controller does not affect the listening rate of the Model 707.) For example, the command string "CA1,H72X" will take 2msec to transmit from the controller to the Model 707.

When the Model 707 is sending data to the controller (e.g., uploading setup data), the transmission rate will typically be 2.5 characters per millisecond.

The bus hold-off time for each command is the time from receipt of the "X" to "instrument configured". It includes the parsing time, data transfers within a master/slave loop, and command execution time.

Table 4-11 summarizes the total times (transmission plus hold-off) for device-dependent commands acting on a stand-alone unit. Table 4-12 summarizes these times for a master and one slave system. Bus hold-off times for individual command strings can be calculated by subtracting the transmission time (four characters per millisecond).

Table 4-11. Typical Transmission and Hold-off Times for a Stand-alone Unit

Description	Command	Time	Notes
External Trigger	A0X	4.8msec	
Matrix Ready	B0X	4.8msec	
Close Crosspoint(s)	CA1X	18.6msec	To relays
	CA1X	19.9msec	To setup 55
	CA1,H72X	21.7msec	To relays
	CA1,H72X	23.1msec	To setup 55
Display	D**********X	10.6msec	
	DX	3.8msec	
Edit Pointer	E0X	4.4msec	
	E100X	5.8msec	
Enable/Disable Triggers	F0X	4.8msec	
Data Format	G7X	4.4msec	
Hit Key	H5X	5.3msec	
Insert Blank Setup	I1X	835msec	
	I100X	21.1msec	
Self-test	J0X	3.3msec	
EOI and Hold-off	K0X	4.4msec	
Download Setup	Lbbb...X	56.0msec	Binary format (G6,G7)
SRQ	M32X	4.9msec	
Open Crosspoint(s)			Similar to "C" times
Digital Output	O255X	5.8msec	
Clear Crosspoints	P0X	18.9msec	
	P55X	20.5msec	
Delete Setup	Q1X	828msec	
	Q100X	21.0msec	
Restore Defaults	R0X	628msec	
Programmed Settling Time	S0X	5.0msec	
	S65000X	7.3msec	
Trigger Source	T7X	4.8msec	
Status	U0X	4.5msec	
	U2,100X	6.8msec	
Make/Break Rows	V00000000X	124msec	With no B/M rows set
	V11111111X	134msec	With no B/M rows set
	V00001111X	153msec	With A,B,C,D as B/M
Break/Make Rows			Similar to "V" times
Execute	X	3.2msec	
Terminator	Y0X	4.7msec	
Copy Setup	Z0,0X	21.1msec	
	Z0,100X	23.3msec	
	Z100,99X	21.6msec	

Table 4-12. Typical Transmission and Hold-off Times for a Master and One Slave

Description	Command	Time	Notes
External Trigger	A0X	12.3msec	
Matrix Ready	B0X	12.3msec	
Close Crosspoint(s)	CA1X	31.5msec	
	CA73X	48.7msec	
	CA1,A73X	51.0msec	
Display	D**********X	17.3msec	
Edit Pointer	E0X	17.4msec	
	E55X	18.8msec	
Enable/Disable Triggers	F0X	18.5msec	
Data Format	G0X	11.7msec	
Insert Blank Setup	I1X	1.7sec	
	I100X	49.9msec	
Self-test	J0X	3.4msec	
EOI and Hold-off	K0X	11.6msec	
Download Setup	Lbbb...X	68.5msec	Binary format (G6,G7)
SRQ	M32X	12.0msec	
Open Crosspoint(s)			Similar to "C" times
Digital Output	O255X	12.9msec	
Clear Crosspoints	P0X	47.8msec	
	P55X	48.8msec	
Delete Setup	Q1X	1.7sec	
	Q100X	49.8msec	
Restore Defaults	R0X	1.4sec	
Programmed Settling Time	S0X	11.9msec	
	S65000X	14.6msec	
Trigger Source	T7X	12.3msec	
Status	U0X	11.8msec	
	U2,100X	14.2msec	
Make/Break Rows	V00000000X	265msec	With no B/M rows set
	V11111111X	284msec	With no B/M rows set
	V00001111X	324msec	With A,B,C,D as B/M
Break/Make Rows			Similar to "V" times
Execute	X	10.5msec	
Terminator	Y0X	11.5msec	
Copy Setup	Z0,0X	51.1msec	
	Z0,100X	47.2msec	
	Z100,0X	55.4msec	
	Z100,99X	49.9msec	

4.12 PROGRAMMING EXAMPLES

The following paragraphs give two examples of how to program the Model 707. As listed, the programs are not necessarily in the most efficient form, but instead are written for clarity in understanding program flow.

The first example (software only) shows how to handle a Model 707 interrupt condition with an SRQ interrupt routine. The second example (software and hardware) shows fast triggering of the Model 707.

4.12.1 Interrupt Example

In this example, an SRQ interrupts the controllers main task when the Model 707 is ready after a triggered setup change. You can program source and measure routines within the interrupt service routine.

A flowchart of the main program is shown in Figure 4-22; the interrupt service routine is shown in Figure 4-23. Highlights of program listed in Figure 4-24 are as follows:

1. Pending SRQs are cleared by serial polling the unit.
2. The interrupt condition (SRQ) and location of the interrupt service routine are defined.
3. The Model 707 is programmed for settling time, break/make rows, and trigger on GET. Stored setups of the unit are modified and the Relay Step Pointer is set to 000.
4. The unit is programmed to generate an SRQ on Matrix Ready by the M8X command.
5. The first setup is triggered. Interrupts are enabled and the main program loops until it detects an interrupt.

When an SRQ occurs, the program will service the SRQ as follows:

1. The Model 707 is first serial polled to obtain the status byte.
2. Bit 6 of the status byte is tested to determine if the SRQ was generated by the Model 707. If not, the service routine returns to the main task. This step is essential when more than one instrument is on the bus.
3. Bit 3 of the status byte is checked to determine if Matrix Ready is asserted. If so, the routine branches to a source/measure subroutine (commented out in this example).
4. Before returning to the main task, a new setup is triggered and interrupts are enabled.

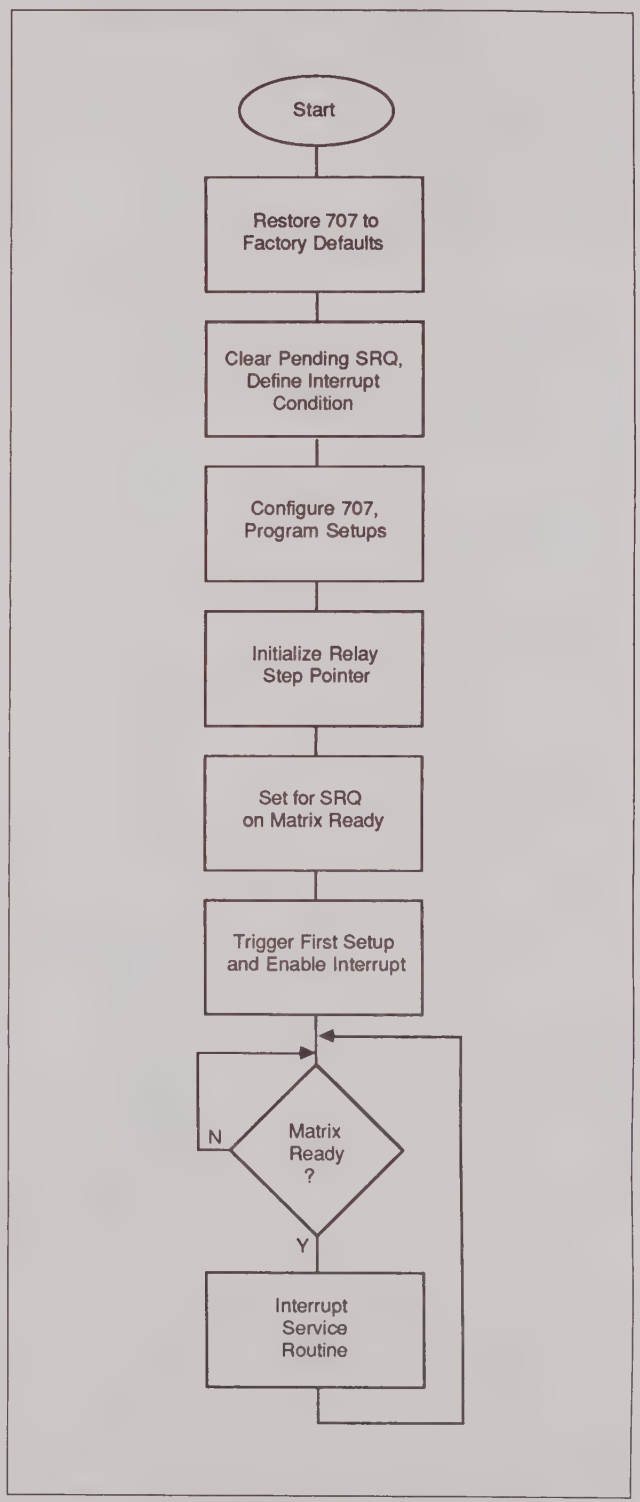


Figure 4-22. Interrupt Example Flowchart (Main Program)

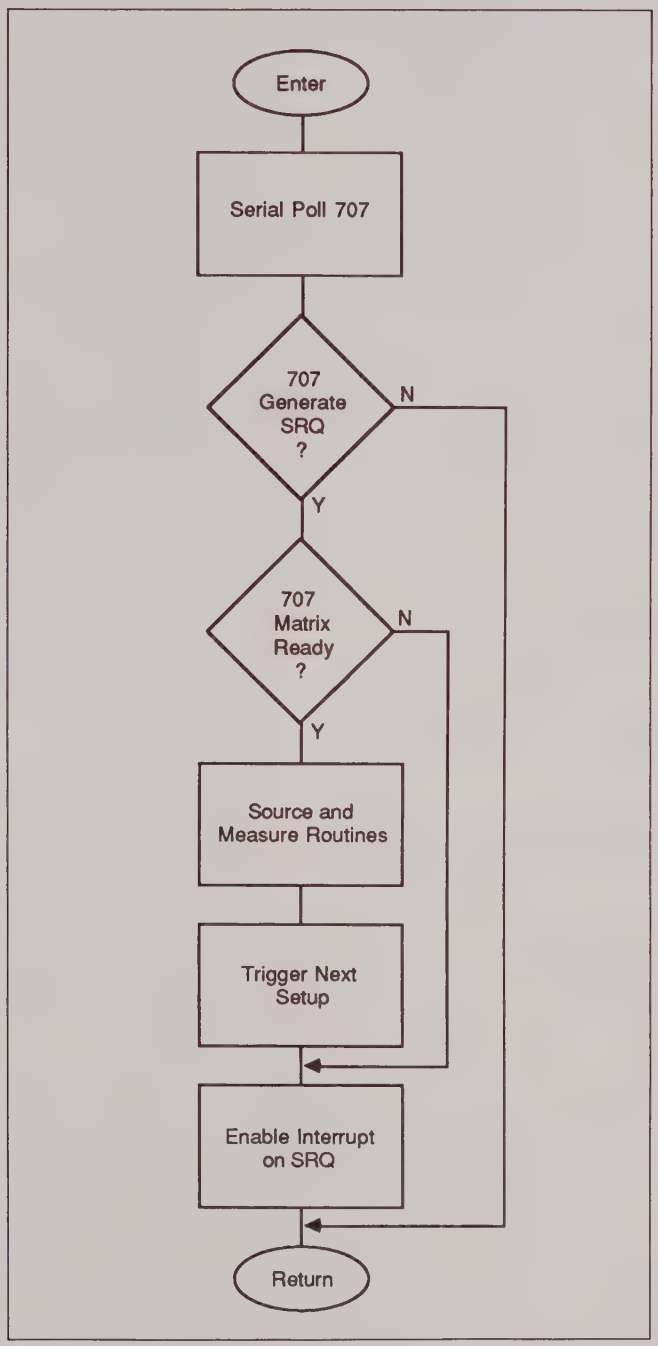


Figure 4-23. Interrupt Example Flowchart (Interrupt Service Routine)

```
 10  ! ADDRESS 718 = MODEL 707 SWITCHING MATRIX
 20  ! ADDRESS 706 = SOURCE INSTRUMENT
 30  ! ADDRESS 714 = MEASURE INSTRUMENT
 40     CLEAR 7                              ! Send device clear to all
 50     OUTPUT 718;''R0X''                   ! Restore 707 factory defaults
 60     S=SPOLL(718)                         ! Clear out pending SRQ
 70     HPIB=7                               ! Define interface select code
 80     MASK=2                               ! Define bit mask
 90     ON INTR HPIB GOSUB SERVICE_ROUTINE   ! Define interrupt initiated branch
100  ! CONFIGURE 707 MATRIX
110     REMOTE 718                           ! Put 707 in remote
120     OUTPUT 718;''S100X''                 ! Program settling time
130     OUTPUT 718;''W11111111X''            ! All rows break/make
140     OUTPUT 718;''T2X''                   ! Trigger on GET
150     OUTPUT 718;''F1X''                   ! Enable triggers
160  ! LOAD SETUPS
170     OUTPUT 718;''E1XCA1,A2X''            ! Setup #1 crosspoints
180     OUTPUT 718;''E2XCB1,B2X''            ! Setup #2 crosspoints
190     OUTPUT 718;''E3XCC1,C2X''            ! Setup #3 crosspoints
200     OUTPUT 718;''E4XCD1,D2X''            ! Setup #4 crosspoints
210  ! SELECT SETUP
220     OUTPUT 718;''Z0,0X''                 ! Select setup #0
230     WAIT .2                              ! Wait for setup to settle
240     OUTPUT 718;''M8X''                   ! Set mask for matrix ready
250     TRIGGER 718                          ! Trigger first setup
260     ENABLE INTR HPIB;MASK                ! Enable interrupts
270  WAIT_MATRIX_RDY:!
280     N=N+1                                ! Wait for matrix to be ready
290     PRINT N                              ! Perform software housekeeping
300     GOTO WAIT_MATRIX_RDY                 ! at this time.
310     STOP
320  SERVICE_ROUTINE:!
330     S=SPOLL(718)                         ! Perform serial poll on 707
340     IF BIT(S,6)=0 THEN RETURN            ! Determine if 707 generated SRQ
350     IF BIT(S,3)=1 THEN GOSUB SOURCE      ! Determine if 707 matrix ready
360     ENABLE INTR HPIB                     ! Enable interrupt on SRQ
370     RETURN
380  SOURCE:!
390     ! OUTPUT 706;CURRENT                 ! Source test stimulus
400  MEASURE:!
410     ! ENTER 714;READING                  ! Make measurement
420     TRIGGER 718                          ! Trigger next setup on 707
430     RETURN
440     END
```

Figure 4-24. Interrupt Example Program Listing

4.12.2 Triggering Example

This example uses the trigger connections of a Model 707, a voltage source, and a DMM to coordinate setup changes for measuring stepped voltages. It will run at a speed of approximately seven milliseconds per setup.

Figure 4-25 shows the trigger connections among the instruments. The switched source and measure paths are shown in Figure 4-26. In this example, no DUTs are used. The system only measures the output of the source.

Program operation is outlined below and flowcharted in Figure 4-27. The program listing is given in Figure 4-28.

1. Model 707 is initialized, setups 91-100 are modified, and the Relay Step pointer is set to 90.
2. A Model 230 voltage source is initialized and programmed to step through 1-10 volts.
3. A Model 196 DMM is initialized and programmed to store ten readings.
4. The voltage source outputs the value of the first step.
5. Model 707 triggers are enabled and a front panel keypress of the MANUAL trigger key is emulated with an H17X command. The following steps occur:
   A. Setup 91 is triggered on the Model 707. Crosspoint A1 is closed.
   B. The MATRIX READY output signal of the Model 707 triggers a reading on the DMM.
   C. VOLTMETER COMPLETE of the DMM triggers the Model 707 to the next setup and the voltage source to the next step.
   D. Steps b and c are repeated for the remaining setups and voltage steps.

A sample output of the program is shown below:

1	.99473
2	1.98907
3	2.99912
4	3.98823
5	4.99827
6	5.99784
7	7.00265
8	7.99699
9	9.0018
10	9.99614

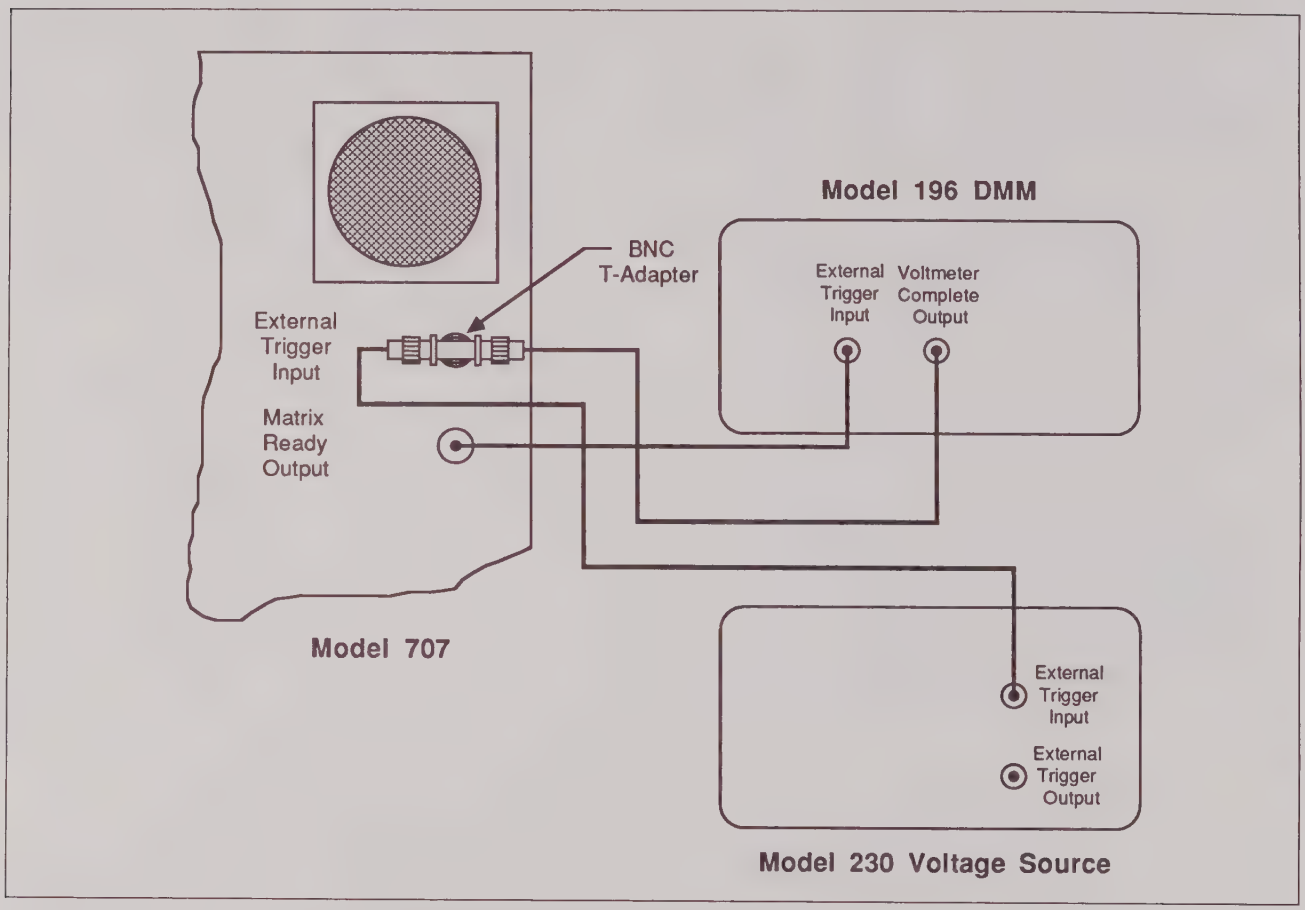


Figure 4-25. Trigger Connections for Triggering Example

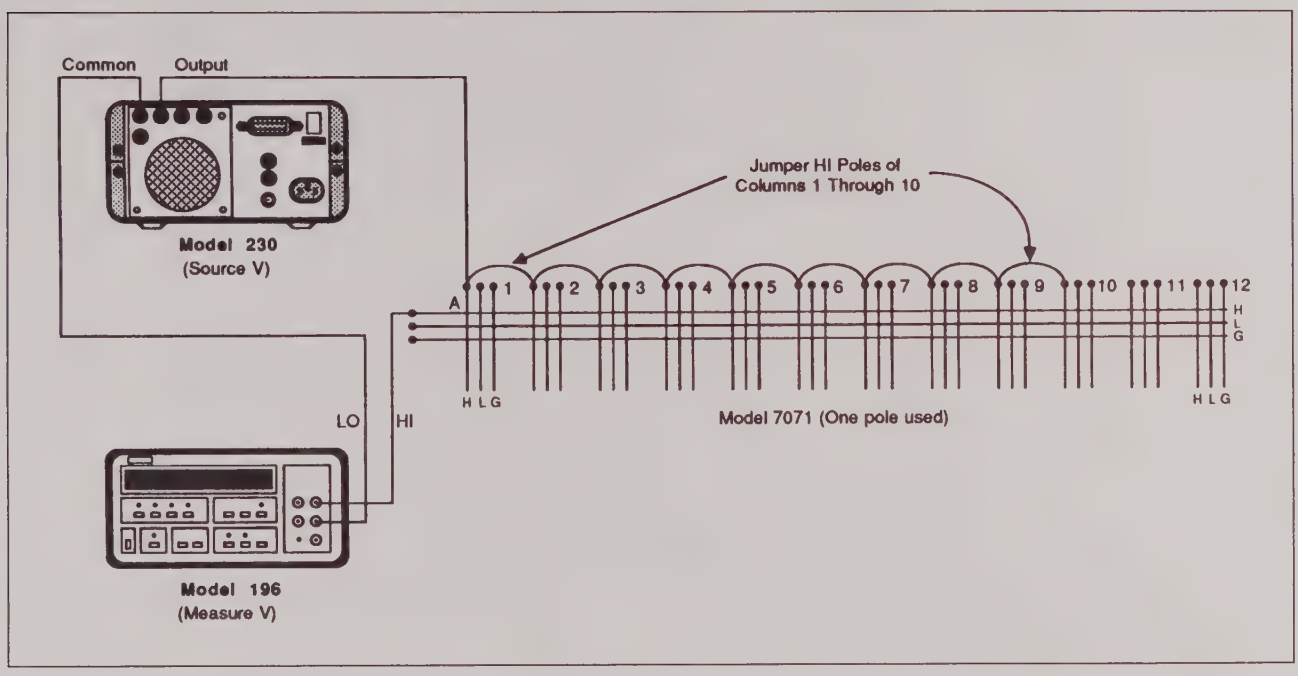


Figure 4-26. Analog Connections for Triggering Example

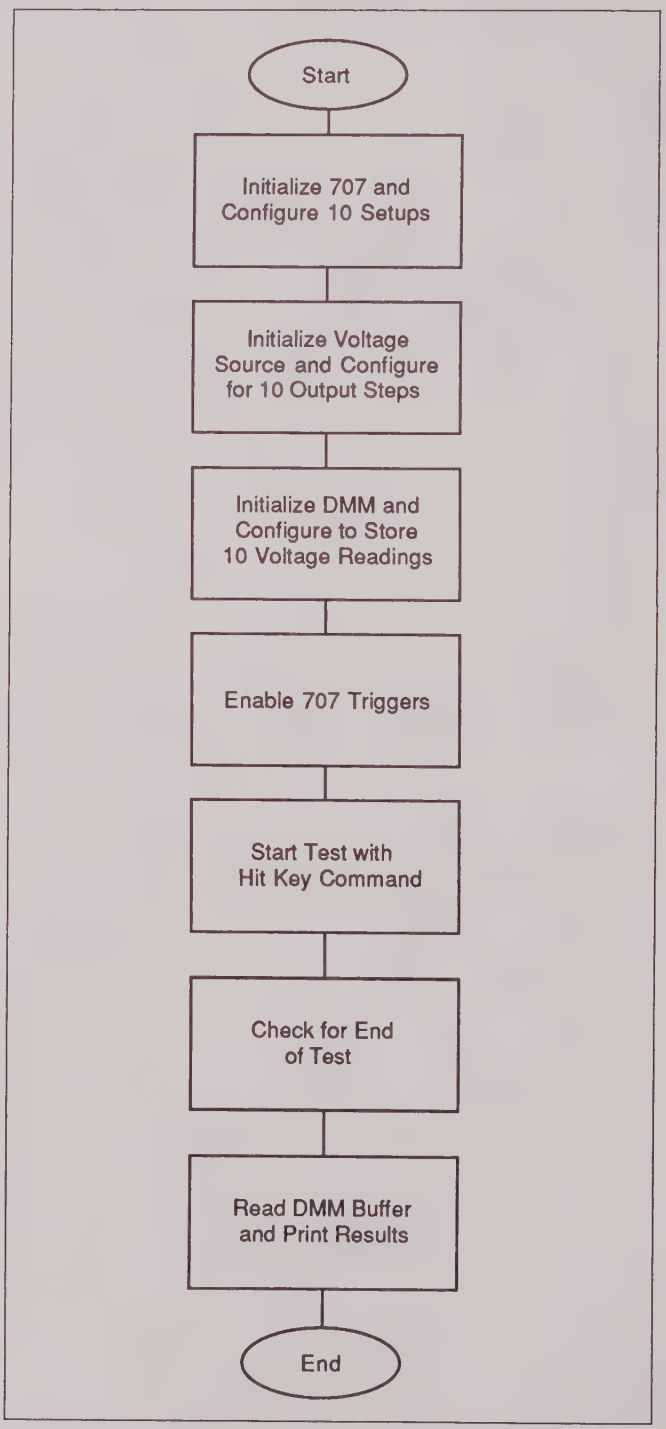

Start
Initialize 707 and Configure 10 Setups
Initialize Voltage Source and Configure for 10 Output Steps
Initialize DMM and Configure to Store 10 Voltage Readings
Enable 707 Triggers
Start Test with Hit Key Command
Check for End of Test
Read DMM Buffer and Print Results
End

Figure 4-27. Triggering Example Flowchart

```
 10  ! ADDRESS 718 = MODEL 707 SWITCHING MATRIX
 20  ! ADDRESS 713 = MODEL 230 PROGRAMMABLE VOLTAGE SOURCE
 30  ! ADDRESS 707 = MODEL 196 DMM
 40    OUTPUT KBD;CHR$(255)&CHR$(75); PRINT                    ! Clear screen
 50    PRINT ''INITIALIZING THE INSTRUMENTS, PLEASE
       WAIT''
 60  ! INITIALIZE THE 707 MATRIX
 70    OUTPUT 718;''R0X''                                      ! Restore defaults (clear 707)
 80    FOR I=91 TO 100                                         ! Select stored setup
 90    C=I-90                                                  ! Select crosspoint column
100    OUTPUT 718;''E''&VAL$(I)&''CA''&VAL$(C)&''X''           ! Configure setups
110    NEXT I
120    OUTPUT 718;''Z90,0X''                                   ! Set Relay Step to 90
130  ! INITIALIZE THE 230 VOLTAGE SOURCE
140    CLEAR 713                                               ! Clear 230
150    OUTPUT 713;''R3I2F1X''                                  ! 10V range, operate ON
160    FOR I=1 TO 10                                           ! Program 10 locations to be 1-10V
170    OUTPUT 713;''B''&VAL$(I)&''L''&VAL$(I)&''U''&
        VAL$(I)&''I2W5E-3X''
180    NEXT I
190  ! INITIALIZE THE 196 DMM
200    CLEAR 707                                               ! Clear 196
210    WAIT 2                                                  ! Wait for DMM autocal
220    OUTPUT 707;''F0R3S0I1000A0N0T7X''                       ! 30Vdc range, 3½ digits, 10
230                                                            ! buffer locations, one-shot
240                                                            ! trigger, auto cal off, internal
250                                                            ! filter off, ext. triggering
260  ! RUN THE TEST
270    OUTPUT KBD;CHR$(255)&CHR$(75);                          ! Clear screen
280    OUTPUT 713;''B1L1X''                                    ! Set Vsource to step 1
290    OUTPUT 718;''F1X''                                      ! Enable 707 triggers
300    OUTPUT 707;''M2X''                                      ! Enable DMM SRQ on buffer full
310    OUTPUT 718;''H17X''                                     ! Emulate 707 front panel trigger
320  CHECK:!
330    STATUS 7,7;S                                            ! Check status register
340    IF BIT(S,10)=0 THEN GOTO CHECK                          ! Test for SRQ
350    S=SPOLL(707)                                            ! Perform serial poll on DMM
360    IF BIT(S,6)=0 THEN GOTO CHECK                           ! Test for SRQ by DMM
370    OUTPUT 707;''B1G1X''                                    ! Set DMM to dump buffer
380    FOR I=1 TO 10                                           ! Read the DMM buffer
390    ENTER 707;D
400    PRINT I,D                                               ! Print readings
410    NEXT I
420    END
```

Figure 4-28. Triggering Example Program Listing

SECTION 5
Principles of Operation

5.1 INTRODUCTION

This section contains a functional description of the Model 707 in block diagram form as well as details of the various sections of the instrument. Information is arranged to provide a description of each of the functional blocks within the instrument. Many of these descriptions include simplified schematics and block diagrams. Detailed schematics and component layout drawings are located at the end of Section 7.

5.2 OVERALL FUNCTIONAL DESCRIPTION

The Model 707 mainframe contains three circuit boards, primarily digital, and two power supplies (5-volt and 6-volt). Relay matrix cards that plug into the mainframe have analog circuits for signal paths and digital circuits for control. Figure 5-1 shows the interconnection of the mainframe's digital board, front panel display board, and backplane in a block diagram.

The following paragraphs describe Model 707 circuitry by function, with some functions residing on more than one board (e.g., relay control circuits and display circuits).

5.3 MICROCOMPUTER

The Model 707 is controlled by an internal microcomputer. As shown in the block diagram of Figure 5-2 and schematic 707-106, the digital board contains the CPU, memory, and associated components:

- 68B09 microprocessor (U6)
- Oscillator (Y1)
- Power-up reset (U17)
- Address decoding PALs (U1, U2)
- 32Kx8-bit EPROM (U7)
- 32Kx8-bit RAM (U8) with battery back-up (BT1, U3)

The microcomputer centers around the 8-bit 68B09 microprocessor. The MPU has direct control over relay switching, front panel displays and switches, and rear panel interfaces (master/slave, digital I/O, IEEE-488 bus, and triggers).

Although the 68B09 microprocessor will operate at frequencies up to 8MHz, a clock frequency of 7.15909MHz is used to reduce interference with instruments that use measurement signals with harmonics of 1MHz. Crystal Y1 provides timing for the microprocessor. Internally, the clock frequency is divided down by four to obtain an operating frequency on the microprocessor bus of 1.78977MHz.

5.3.1 Reset Circuit

The reset circuit, which is based on an 8211 (or 6728) voltage detector (U17), senses the output of the 5-volt power supply. When the output drops below approximately 4.6V, the 8211 asserts the RESET (low true) line. Two 1% resistors (R34 and R35) form a voltage divider, which is calibrated to match the comparator threshold voltage of the 8211 by either removing or leaving in R36, which is in parallel with R35.

During power-off or brownout conditions, the RESET line must be asserted before the 5-volt supply drops into the comparator threshold range (4.25 to 4.5 volts) of the DS-1210 non-volatile RAM controller (U3). During power-up, capacitor C91 is charged up to delay the RESET line going high for 110 to 260msec.

5.3.2 Address Decoding

U1, a 16P8A programmable array logic (PAL) chip, decodes microprocessor address lines A15-A12 for the 32K EPROM ($8000-$FFFF) and the 32K bytes of bank-selected RAM ($0000-$2FFF). Bank selection is used so that the RAM appears as 12K bytes of address space to the microprocessor.

U1 also decodes the three bank-select lines (BS3-BS0) from the PB6-PB4 outputs of U9, a 6522A versatile interface adapter (VIA). The RAM is decoded as 8K bytes ($0000-$1FFF) and six 4K byte banks, which appear to the microprocessor at addresses $2000-$2FFF. This permits the microprocessor to select one of the six 4K byte banks.

Address decoding for peripheral devices on the microprocessor bus is performed by another 16P8A PAL

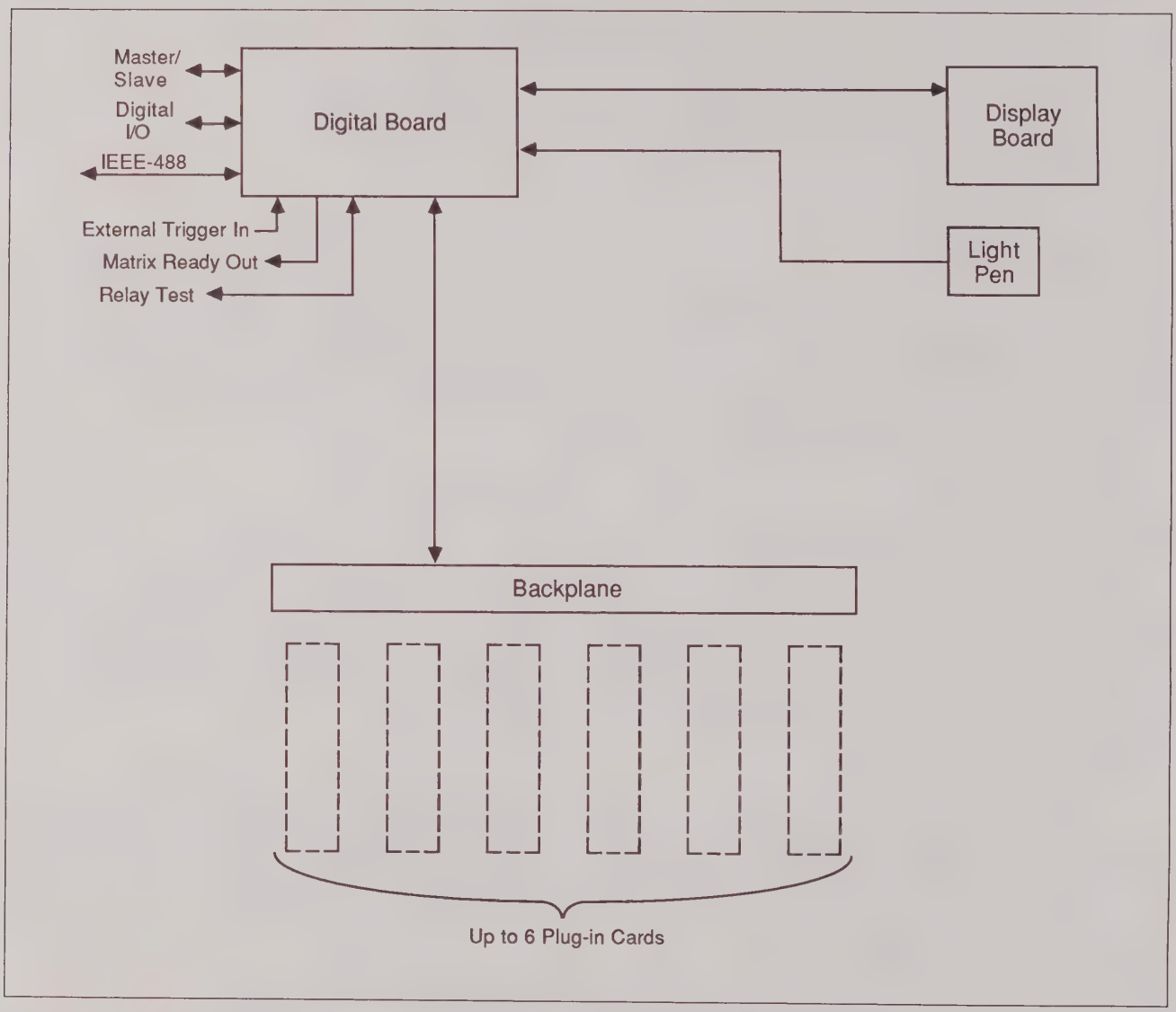


Figure 5-1. Model 707 Block Diagram

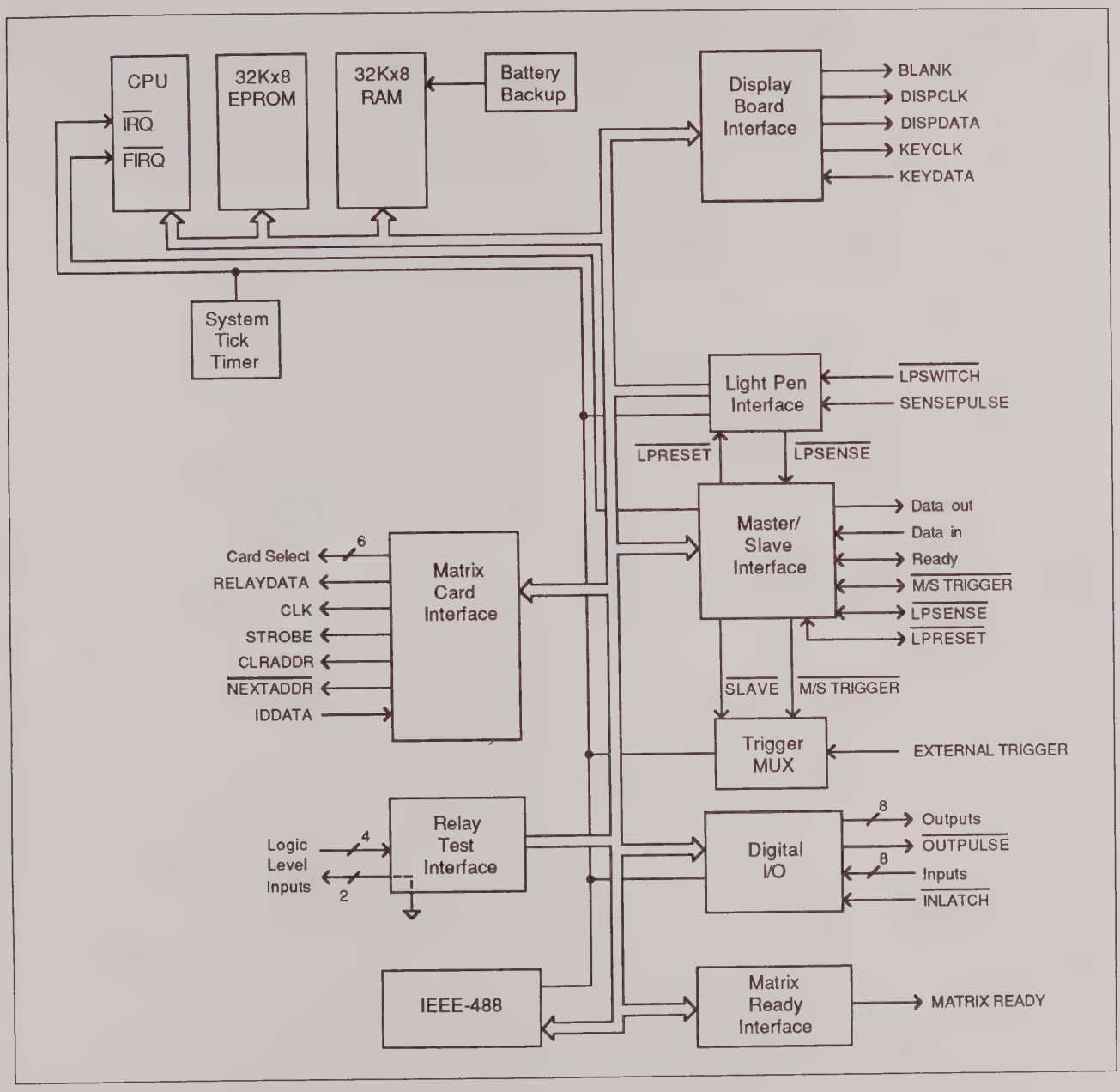


Figure 5-2. Digital Board Block Diagram

(U2). Peripheral devices are decoded at 16-byte intervals in the address range of $3800-$38FF. These include, for example, a 6522A VIA, a 65C21 peripheral interface adapter (PIA), and a 68B50 asynchronous communication interface adapter (ACIA).

5.3.3 Memory

The 32K bytes of instrument operation software are stored in U7, which is a 27256 EPROM. The revision level of the software is displayed on power-up.

U8 is a 32K byte static CMOS RAM chip that is used for storing relay setups and as a scratchpad during normal operation. Its power source and chip enable lines are routed through U3, a DS-1210 NVRAM controller. Figure 5-3 shows a simplified schematic of the RAM and battery back-up circuitry.

The NVRAM controller performs the functions of switching the RAM power source between Vcc and the lithium battery (BT1). It also disables chip enable (CE) to the RAM when Vcc is outside the specified limits. (See the paragraph describing the reset circuitry.)

In addition, if the battery power goes below a specified limit while Vcc is not present, a DS-1210 chip normally inhibits the second chip enable signal to the RAM after Vcc is restored. Since this feature is not used in the Model 707, the software always does a dummy read of memory locations $0000-$0001 on power-up to get past the second chip enable cycle. This permits the Model 707 to operate properly with no battery, or if the battery has been replaced.

5.4 RELAY CONTROL CIRCUITRY

The relay control circuits reside on the backplane board, digital board, and each matrix card.

The backplane board acts as a passive conduit for:

- Control signals from the digital board to the matrix cards and response from the matrix cards to the digital board.
- Power lines to the matrix cards.
- Expansion of analog signals among the matrix cards.

Operations of relay control circuitry on the digital board and a typical matrix card are described in the following paragraphs.

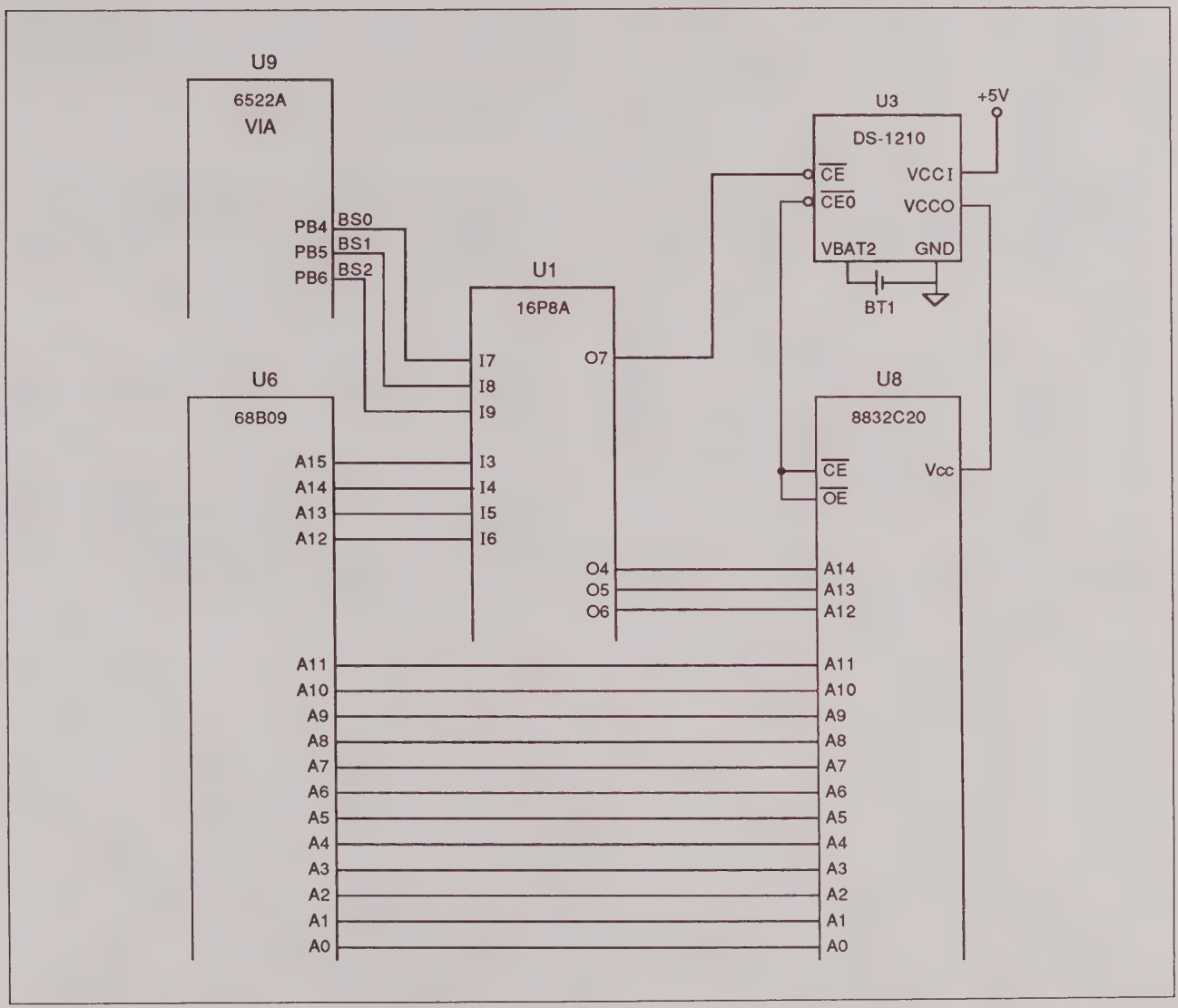


Figure 5-3. RAM and Battery Backup

5.4.1 Matrix Card Interface

A simplified schematic and timing diagram of the digital board's matrix card interface are shown in Figures 5-4 and 5-5. Also see schematic 707-106.

The microprocessor reads card identification data from the EPROM on each installed matrix card during power-up, and also sends relay control data to the matrix cards during the course of operation. This data is sent and received in serial form.

On the digital board, U25, U26, U5, U22, and U24 form an 8-bit parallel-in, serial out data converter. When the microprocessor executes a write to the address decoded for U25 (a 74HCT165 shift register), the data bus contents are loaded into U25, and all ones are loaded into U26 (another 74HCT165) causing its output OH to go high.

At the end of the write cycle, the SELECT RELAYDATA decode line goes high, causing the output of the U5 (74HCT08) AND gate to go high. This signal (ACTIVE) gates the microprocessor E clock through a U22 (74HCT00) NAND, which is buffered by U28 and sent to the matrix cards as the CLK signal. Clock cycles are counted by the U26 shift register. After 8 cycles, OH of U26 returns low, disabling further CLK pulses.

The U24 (74HCT74) flip-flop and another U22 NAND gate are used to create an inverted version of CLK, which does not start until after one cycle of CLK. This signal is used to shift data out of the U25 RELAYDATA shift register.

5.4.2 Matrix Card Logic

See Figure 5-6 for a block diagram of the logic on a typical matrix card.

ON the matrix cards, the CLK and RELAYDATA signals are buffered and sent to a string of UCN-5841 serial input latched driver chips. The CLK signal is sent in parallel to all of the driver ICs and the serial data out of one driver is connected to the serial data in of the next.

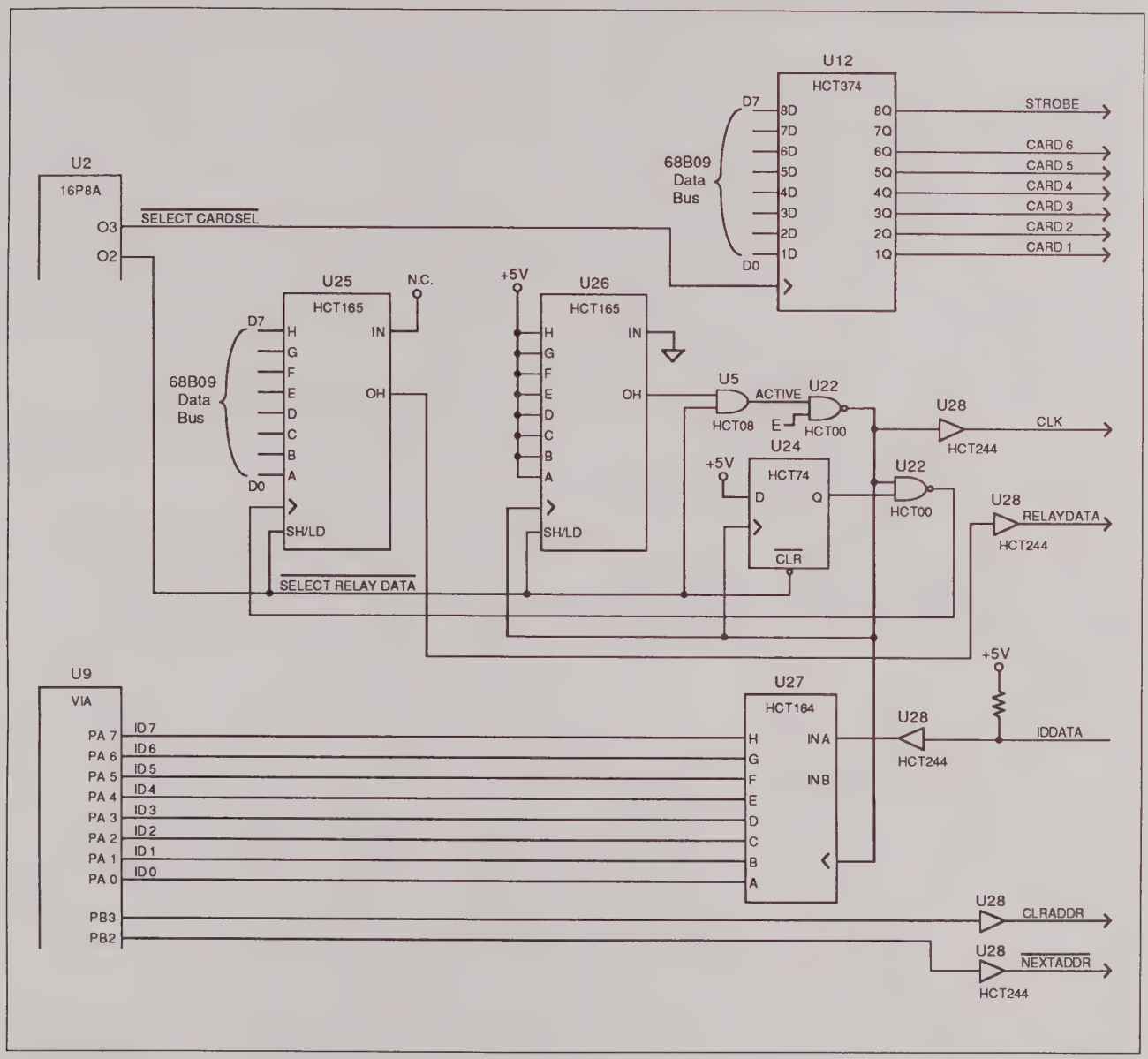


Figure 5-4. Matrix Card Interface Simplified Schematic

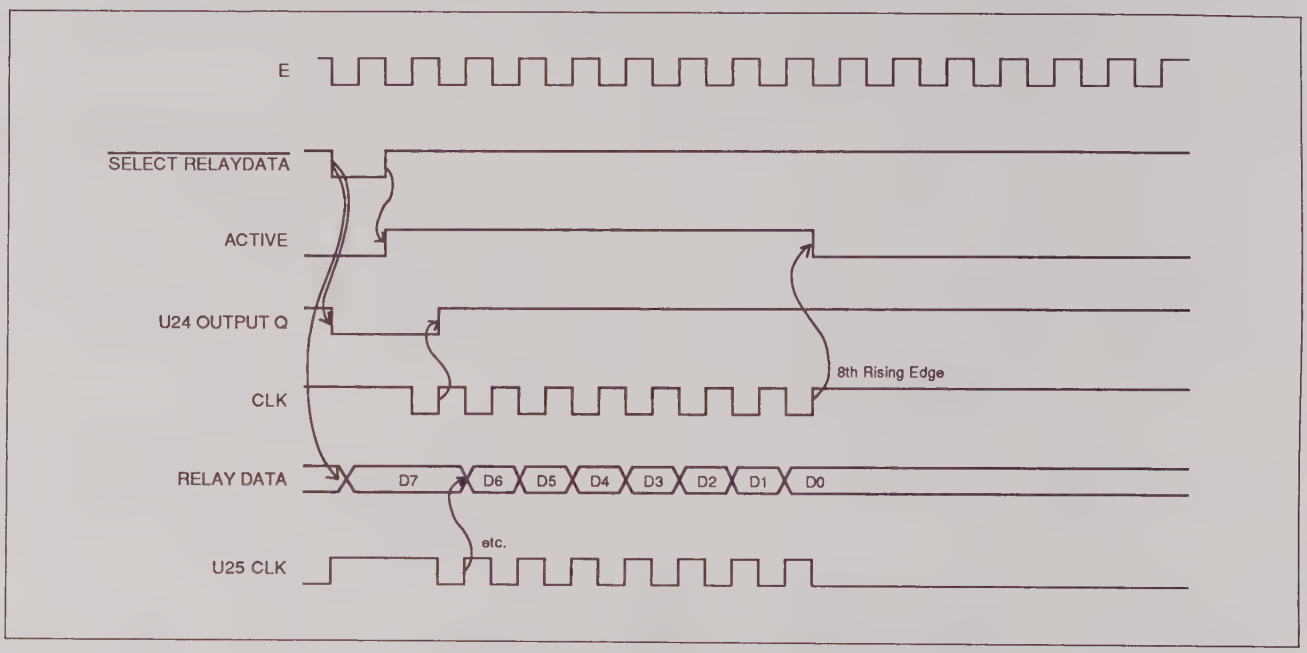


Figure 5-5. Matrix Card Interface Timing Diagram

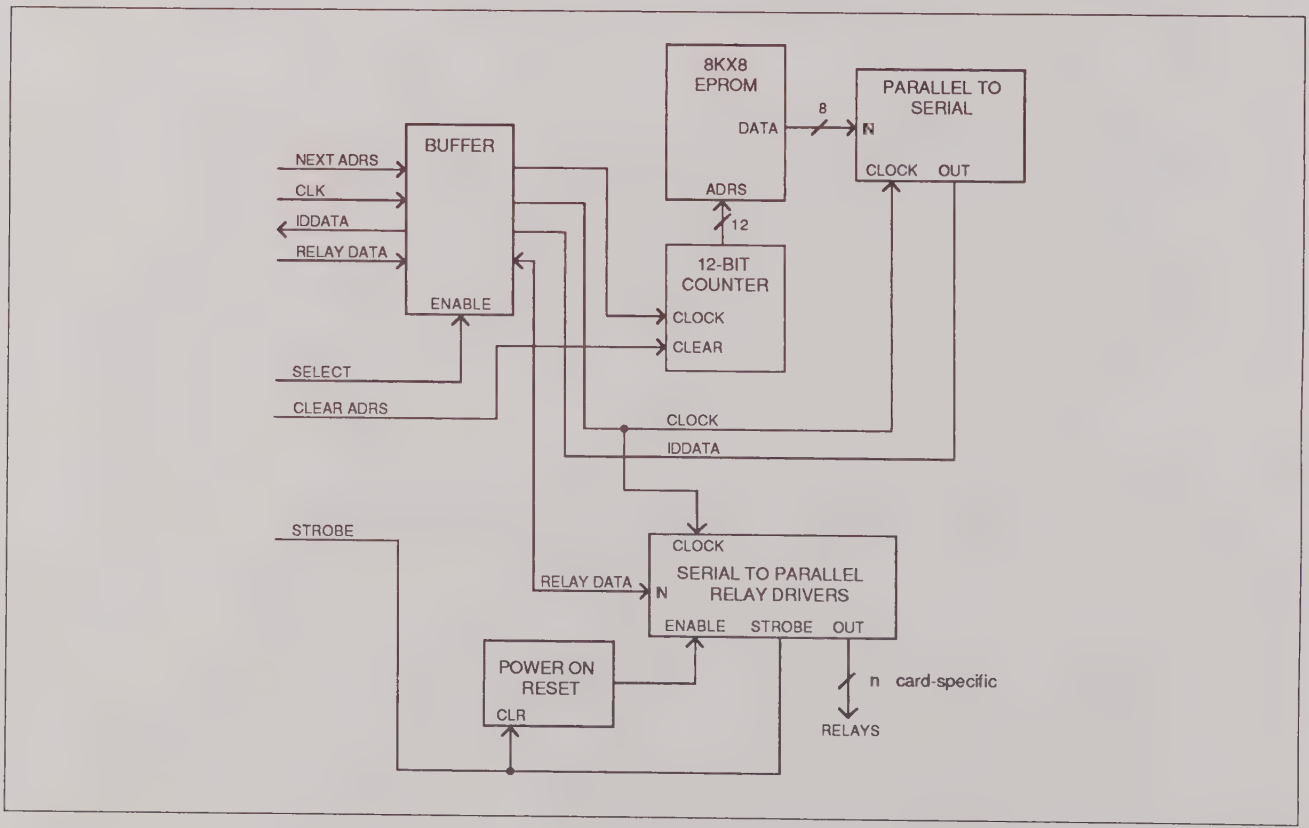


Figure 5-6. Typical Matrix Card Logic Block Diagram

ID Data Circuits

Each matrix card has a 2764 EPROM that contains the following identification data:

- Card model number
- Relay (hardware) settling time
- Relay configuration table

The configuration table defines the location of each relay driver within the serial RELAYDATA bit stream. The table is necessary because the physical layout of matrix cards varies. In addition, the table accomodates row and/or column isolation relays, such as those on the Model 7072 card.

To read this ID data, the sequence below is performed upon power-up. Figure 5-7 shows the general timing of this sequence.

1. The CARDSEL line is brought low, enabling the EPROM outputs. This line remains low throughout the ID data transmission sequence.
2. The CLRADDR line (generated by port signal PB3 of the digital boards VIA) is pulsed high to clear the 12-bit address counter (74HCT4040) to zero. At this point, an EPROM address of zero is selected. This pulse occurs only once.
3. The NEXTADDR line (PB2 of VIA) is set low. This increments the counter and enables parallel loading of the parallel-to-serial converter (74HCT165). NEXTADDR is kept low long enough for the counter to increment and the EPROM outputs to stabilize. This sequence functions because the LOAD input of the parallel-to-serial converter is level-sensitive rather than edge-sensitive. The first EPROM address used by the Model 707 is location one, not zero.
4. The same CLK signal that shifts RELAYDATA into the relay driver also clocks the parallel-to-serial converter to shift all eight data bits from the converter to the digital board via the IDDATA line. (This means that a byte of RELAYDATA must be sent to a matrix card to get the next byte of IDDATA.

Steps 3 and 4 are repeated until all the necessary EPROM locations are read.

As seen in Figure 5-4 of the digital board, IDDATA is converted back to parallel by U27 (74HCT164) and is read by the microprocessor through the port A lines of U9 (6522A VIA).

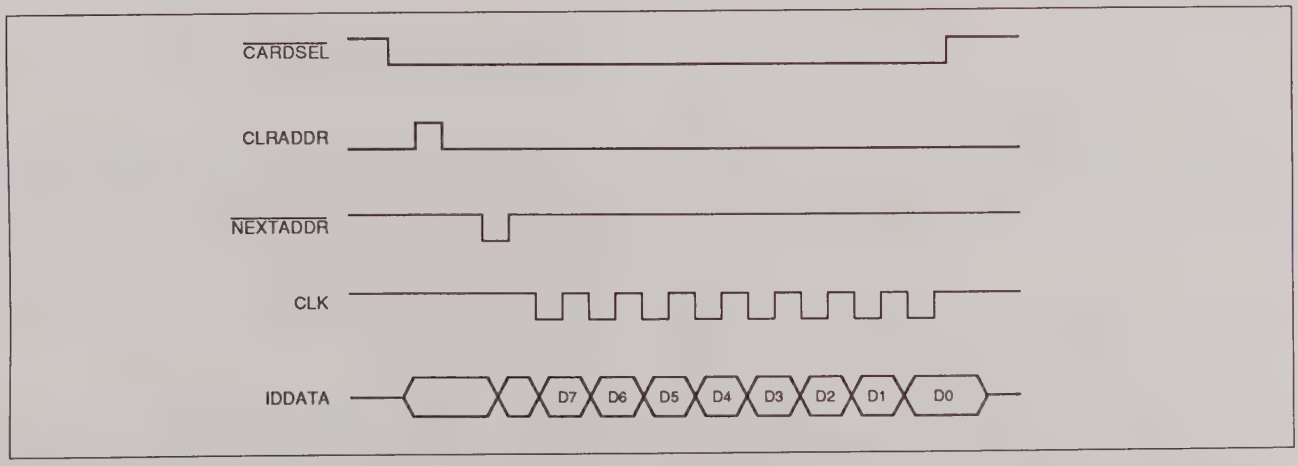


Figure 5-7. IDDATA Timing Diagram

Relay Control

The CLK, RELAYDATA, and IDDATA lines are bused to all six card slots on the backplane board. A separate card select signal is sent to each matrix card to enable it for receiving RELAYDATA and sending IDDATA. The microprocessor controls the card select signals through U12 (74HCT374) on the digital board, which is decoded as an output port on the microprocessor bus.

The relays are controlled by the serial data transmitted via the RELAYDATA lines. Bytes for each card are shifted serially into latches located in the relay drivers. The serial data is fed in through the DATA lines under control of the CLK signal. As data overflows one register, it is fed out the Q'S line of that register to the next IC down the chain.

Once all the bytes have been shifted into each card in the mainframe, the STROBE line is set high to latch the relay information into the Q outputs of the relay drivers, and the appropriate relays are energized (assuming the driver outputs are enabled, as discussed below). Logic convention is such that the corresponding relay driver output must be low to energize the associated relay, while the output is high when the relay is de-energized. The STROBE signal is received by all matrix cards regardless of the state of their respective card select lines.

Power-on Safeguard

Each matrix card has a power-on safeguard circuit to ensure that relays do not randomly energize upon power-up. Two NAND gates of a 74HCT00 are configured as an R-S flip-flop. On power-up, the Q output of the flip-flop is set high, holding the low true OEN (output enable) pins of the relay drivers high. Hence, the driver outputs are disabled and all relays remain de-energized regardless of the relay data information present at that time.

The falling edge of the first STROBE pulse that comes along (to load relay data) clears the R-S flip-flop, setting the OEN pins low and enabling the driver outputs. (At this time, valid relay control data has been sent to the matrix cards and is present in the latches of the driver chips.) This action allows the relays to be controlled by the transmitted relay data information.

NOTE

The STROBE signal can be high or low on power-up since the outputs of U12 (74HCT374) on the digital board are undefined at power-on. Since a falling edge on STROBE, after the Output Enable circuit times out, enables the relay driver outputs, the power-up software must set STROBE low before the time-out. It then pulses STROBE high only after the relay driver shift registers have been cleared.

A hold-off period (typically 470msec) is included in the safeguard circuit to guard against premature enabling of the relays. The time constant of the hold-off period is determined by an R-C network.

5.5 DISPLAY CIRCUITRY

Model 707 display circuitry includes components needed to control the alphanumeric display, front panel annunciator LEDs, crosspoint LEDs, make/break and break/make LEDs, and needed to read front panel switches.

The display circuitry resides on the display board and digital board. See Figure 5-8 for a block diagram of the display board and Figure 5-9 for a simplified schematic of the display board interface on the digital board. Also refer to schematics 707-116 and 707-106 at the end of Section 7.

The front panel display is multiplexed as 15 columns of up to 63 segments each:

- There are 14 columns of alphanumeric display digits, plus a 15th column containing the discrete annunciator LEDs (TALK, LISTEN, REMOTE, MEMORY, RELAYS, etc.).
- There are 12 columns of crosspoint display LEDs. They line up under the right-most 12 alphanumeric digits.
- There is one column of Make/Break and Break/Make LEDs. It lines up under the column containing the discrete annunciators.

The first 15 display segments are the 14-segment plus decimal point alphanumeric digits (in columns 1-14), or the discrete annunciators (in column 15). The remaining 48 display segments are divided into six groups of eight, one group for each block of crosspoint displays (for columns 1-12), or for the Make/Break and Break/Make LEDs (for column 15). Segment assignments for the multiplexed columns are shown in Table 5-1.

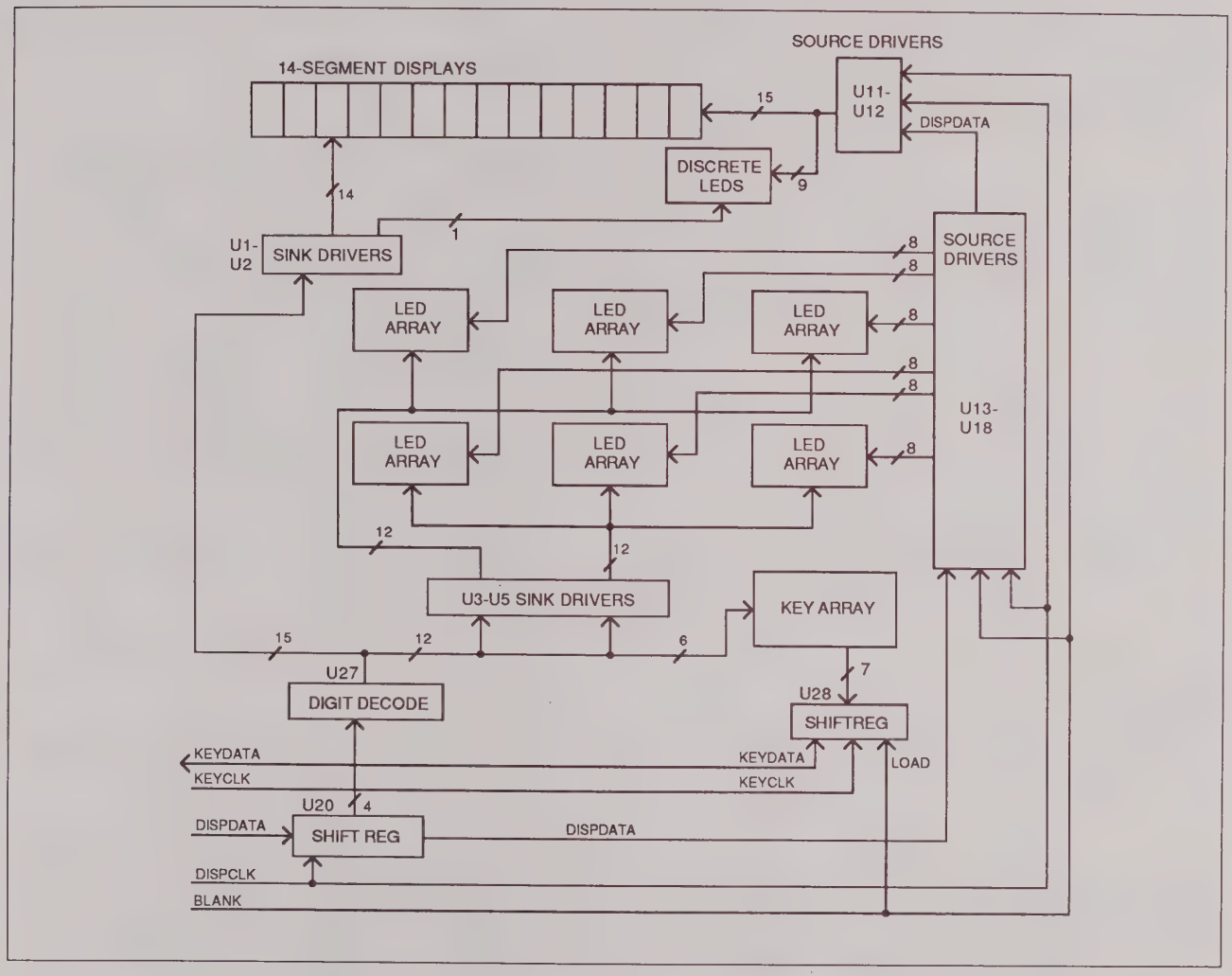


Figure 5-8. Display Board Block Diagram

Table 5-1. Display Segment Assignments

Display Segments	Display MUX Columns							
	15	14	13	12	11	10	9	8
1-15	Annunciator LEDs DS32-DS40	Alphanumeric Digit 1 DS1 (MSD)	Alphanumeric Digit 2 DS1	Alphanumeric Digit 3 DS2	Alphanumeric Digit 4 DS2	Alphanumeric Digit 5 DS3	Alphanumeric Digit 6 DS3	Alphanumeric Digit 7 DS4
16-23	Upper Make/ Break LEDs DS8-DS9			Card 1 Column 1 DS8-DS9	Card 1 Column 2 DS8-DS9	Card 1 Column 3 DS8-DS9	Card 1 Column 4 DS8-DS9	Card 1 Column 5 DS8-DS9
24-31				Card 2 Column 1 DS12-DS13	Card 2 Column 2 DS12-DS13	Card 2 Column 3 DS12-DS13	Card 2 Column 4 DS12-DS13	Card 2 Column 5 DS12-DS13
32-39	Upper Break/ Make LEDs DS18-DS19			Card 3 Column 1 DS16-DS17	Card 3 Column 2 DS16-DS17	Card 3 Column 3 DS16-DS17	Card 3 Column 4 DS16-DS17	Card 3 Column 5 DS16-DS17
40-47	Lower Make/ Break LEDs DS20-DS21			Card 4 Column 1 DS20-DS21	Card 4 Column 2 DS20-DS21	Card 4 Column 3 DS20-DS21	Card 4 Column 4 DS20-DS21	Card 4 Column 5 DS20-DS21
48-55				Card 5 Column 1 DS24-DS25	Card 5 Column 2 DS24-DS25	Card 5 Column 3 DS24-DS25	Card 5 Column 4 DS24-DS25	Card 5 Column 5 DS24-DS25
56-63	Lower Break/ Make LEDs DS30-DS31			Card 6 Column 1 DS28-DS29	Card 6 Column 2 DS28-DS29	Card 6 Column 3 DS28-DS29	Card 6 Column 4 DS28-DS29	Card 6 Column 5 DS28-DS29

Display Segments	Display MUX Columns							
	7	6	5	4	3	2	1	
1-15	Alphanumeric Digit 8 DS4	Alphanumeric Digit 9 DS5	Alphanumeric Digit 10 DS5	Alphanumeric Digit 11 DS6	Alphanumeric Digit 12 DS6	Alphanumeric Digit 13 DS7	Alphanumeric Digit 14 DS7 (LSD)	
16-23	Card 1 Column 6 DS10-DS11	Card 1 Column 7 DS10-DS11	Card 1 Column 8 DS10-DS11	Card 1 Column 9 DS10-DS11	Card 1 Column 10 DS10-DS11	Card 1 Column 11 DS10-DS11	Card 1 Column 12 DS10-DS11	
24-31	Card 2 Column 6 DS12-DS13	Card 2 Column 7 DS14-DS15	Card 2 Column 8 DS14-DS15	Card 2 Column 9 DS14-DS15	Card 2 Column 10 DS14-DS15	Card 2 Column 11 DS14-DS15	Card 2 Column 12 DS14-DS15	
32-39	Card 3 Column 6 DS16-DS17	Card 3 Column 7 DS16-DS17	Card 3 Column 8 DS18-DS19	Card 3 Column 9 DS18-DS19	Card 3 Column 10 DS18-DS19	Card 3 Column 11 DS18-DS19	Card 3 Column 12 DS18-DS19	
40-47	Card 4 Column 6 DS22-DS23	Card 4 Column 7 DS22-DS23	Card 4 Column 8 DS22-DS23	Card 4 Column 9 DS22-DS23	Card 4 Column 10 DS22-DS23	Card 4 Column 11 DS22-DS23	Card 4 Column 12 DS22-DS23	
48-55	Card 5 Column 6 DS24-DS25	Card 5 Column 7 DS26-DS27	Card 5 Column 8 DS26-DS27	Card 5 Column 9 DS26-DS27	Card 5 Column 10 DS26-DS27	Card 5 Column 11 DS26-DS27	Card 5 Column 12 DS26-DS27	
56-63	Card 6 Column 6 DS28-DS29	Card 6 Column 7 DS28-DS29	Card 6 Column 8 DS30-DS31	Card 6 Column 9 DS30-DS31	Card 6 Column 10 DS30-DS31	Card 6 Column 11 DS30-DS31	Card 6 Column 12 DS30-DS31	

Note:
MSD - most significant digit
LSD - least significant digit

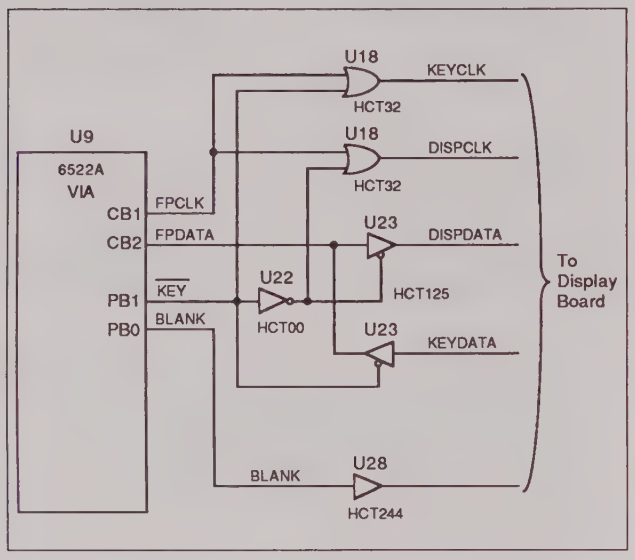


Figure 5-9. Display Interface Simplified Schematic

5.5.1 Display Data

The digital board sends display data (DISPDATA) to the display board serially. Nine bytes are required: eight bytes of segment data and one byte to select the column.

All displays are arranged as common cathode. The segment anodes are driven by source drivers U11-U18 (UCN5895A) connected in a serial data chain. Each source driver has eight outputs and an output disable. (While new data is being sent to the display drivers, the BLANK line is set high to disable the outputs.) Display data is first shifted into serial-to-parallel converter U20 (74HCT164) and then to the chain of segment source drivers.

Four parallel outputs of U20 are decoded by the 4-to-16 decoder U27 (74HCT154). The outputs of this decoder drive the display cathodes through sink drivers U1-U5 (UDN2597A).

5.5.2 Front Panel Keys

The front panel keys are SPST normally-open pushbutton switches. They are connected in a 6-column by 7-row array. Each column is connected to one of the column drive outputs of decoder U27 (74HCT154) through a diode. The diodes isolate the columns from one another in case more than one key on the same row is pressed. As the display is multiplexed, each key column is pulled low in its turn. The other columns float.

Each row is connected to Vcc through a pull-up resistor and to one of the inputs of parallel-to-serial converter U28 (74HCT165). The load input of U28 is connected to the BLANK signal, so that each time new data is sent to the display, another column of the key array gets latched into U28.

5.5.3 Display Interface

The display interface circuitry of the digital board generates clock signals and communicates serial data for the front panel display and keyboard. The shift register of U9 (6522A VIA) controls the display and reads the key array. Pin CB1 is the clock signal (FPCLK) and pin CB2 is the data signal (FPDATA).

Signal FPCLK is generated for both serial output (display) and serial input (keyboard) operations. This single bi-directional port is converted to two uni-directional ports by two OR gates of U18 (74HCT32), two tri-state drivers of U23 (74HCT125), and a NAND gate of U22 (74HCT00) used as an inverter.

When the low true KEY signal (generated on VIA pin PB1) is asserted, DISPCLK is held high, KEYCLK follows FPCLK, the KEYDATA driver (U23) is enabled, and the DISPDATA driver (U23) is disabled.

When the low true KEY signal is negated, the KEYCLK signal is held high and the DISPCLK signal follows FPCLK. Also, the KEYDATA driver is disabled while the DISPDATA driver is enabled. The remaining signal that goes to the display board, BLANK, is generated by VIA output pin PB0.

5.5.4 Refresh Display/Read Keyboard

The refresh display/ read keyboard sequence is as follows:

NOTE

During power-on hardware initialization, the U9 shift register (6522A VIA) is configured for output and the low true KEY signal is negated.

1. Set the BLANK line high.
2. Send nine bytes of DISPDATA out the VIA shift register to drive the next column in the multiplex sequence.
3. Set the BLANK line low.
4. Configure the VIA shift register for input.
5. Assert the low true KEY line.
6. Read the VIA shift register to cause the KEYDATA to be shifted into the VIA.
7. Read the VIA shift register again to get the byte of KEYDATA.
8. Negate the low true KEY line.
9. Configure the VIA shift register for output.

5.6 LIGHT PEN INTERFACE

The light pen interface circuitry resides on the digital board. A simplified schematic is shown in Figure 5-10.

The light pen is a self-contained unit requiring only a 5-volt supply. It returns two TTL-compatible signals:

- SENSEPULSE — A low-going pulse of about 15μsec width that occurs as the light intensity at the end of the pen rises above a preset threshold.
- LPSWITCH — A debounced switch signal that is low while the light pen pushbutton is depressed.

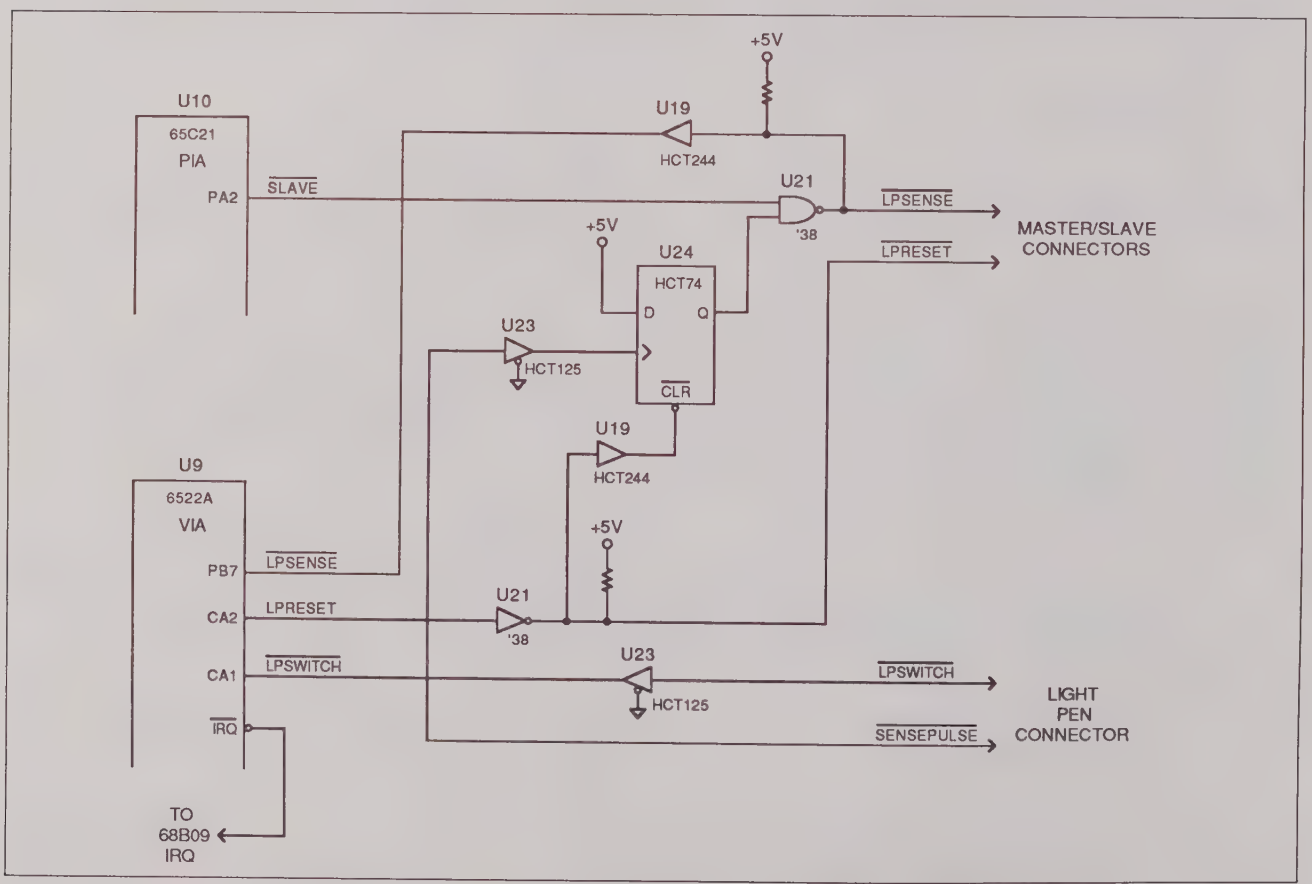


Figure 5-10. Light Pen Interface Simplified Schematic

The rising edge of SENSEPULSE clocks a high into flip-flop U24 (74HCT74). This converts the signal into a level that can be read by the microprocessor through the PB7 input of U9 (6522A VIA) as signal LPSENSE (low true).

If the low true SLAVE signal from U10 (65C21 PIA) is high (i.e., the unit is either a stand-alone or master), the microprocessor reads its own U24 flip-flop. The output of U24 also gets driven onto the LPSENSE line of the master/slave connectors. If SLAVE is asserted, the microprocessor reads the LPSENSE signal from the master/slave connectors.

The microprocessor can clear flip-flop U24 by setting the LPRESET output of U9 high. This signal also gets driven onto the master/slave connectors by open-collector driver U21. This method permits the master and all slaves in a master/slave system to read and clear the U24 flip-flop in the master unit. Thus, one light pen can serve for all units, while each unit controls its own display for the scan routine.

The switch signal (low true LPSWITCH) goes to the CA1 interrupt input of the VIA, which is programmed to generate an IRQ interrupt on the falling edge of LPSWITCH. The interrupt service routine stops the normal display refresh multiplexing and takes over control of the display.

The routine then scans the display one column at a time, clearing flip-flop U24 before scanning each column. After the display is scanned, the processor examines the LPSENSE signal to determine if the light pen "sees" one of the LEDs that is currently being scanned.

If a master scans its display and gets no response from the light pen, it instructs the slaves in turn to scan their displays. Each slave monitors the U24 flip-flop of the master to check whether or not the light pen "sees" any of the LEDs that are lit on its own display.

5.7 MASTER/SLAVE CIRCUITRY

The master/slave interface is a closed loop of serial communication and bused control signals. Its control circuitry resides on the digital board. See Figure 5-11 for a simplifed schematic.

Each mainframe has a Master/Slave In connector and a Master/Slave Out connector. Serial data is sent from the TXDATA pin of the output connector to the RXDATA pin of the input connector on the next mainframe in the loop. All other interface signals (M/S TRIGGER, ALLREADY, LPRESET, and LPSENSE) are common to input and output connectors. The light pen signals LPRESET and LPSENSE are described in paragraph 5.6.

5.7.1 Serial Communication

Serial data communication is managed by U11 (68B50 ACIA) and automatic retransmit logic: a U22 NAND gate used as an inverter, U5 AND gates, and U18 OR gate.

The RTS (low true) output of U11 controls the automatic retransmission of serial data. Stand-alone and master units assert RTS to gate the TXDATA output of U11 through a U5 AND gate and via U18 onto the TXDATA pin of the master/slave interface. Relay K1 is energized (as shown) whenever power is applied to the Model 707.

Slave units negate RTS except when responding to a request by the master for setup or status information. A negated RTS signal blocks the TXDATA signal at its corresponding U5 AND gate. Incoming serial data to the RXDATA input of U11 is also routed through a U5 gate, the U18 OR gate, and onto the master/slave TXDATA pin to effect the automatic retransmission.

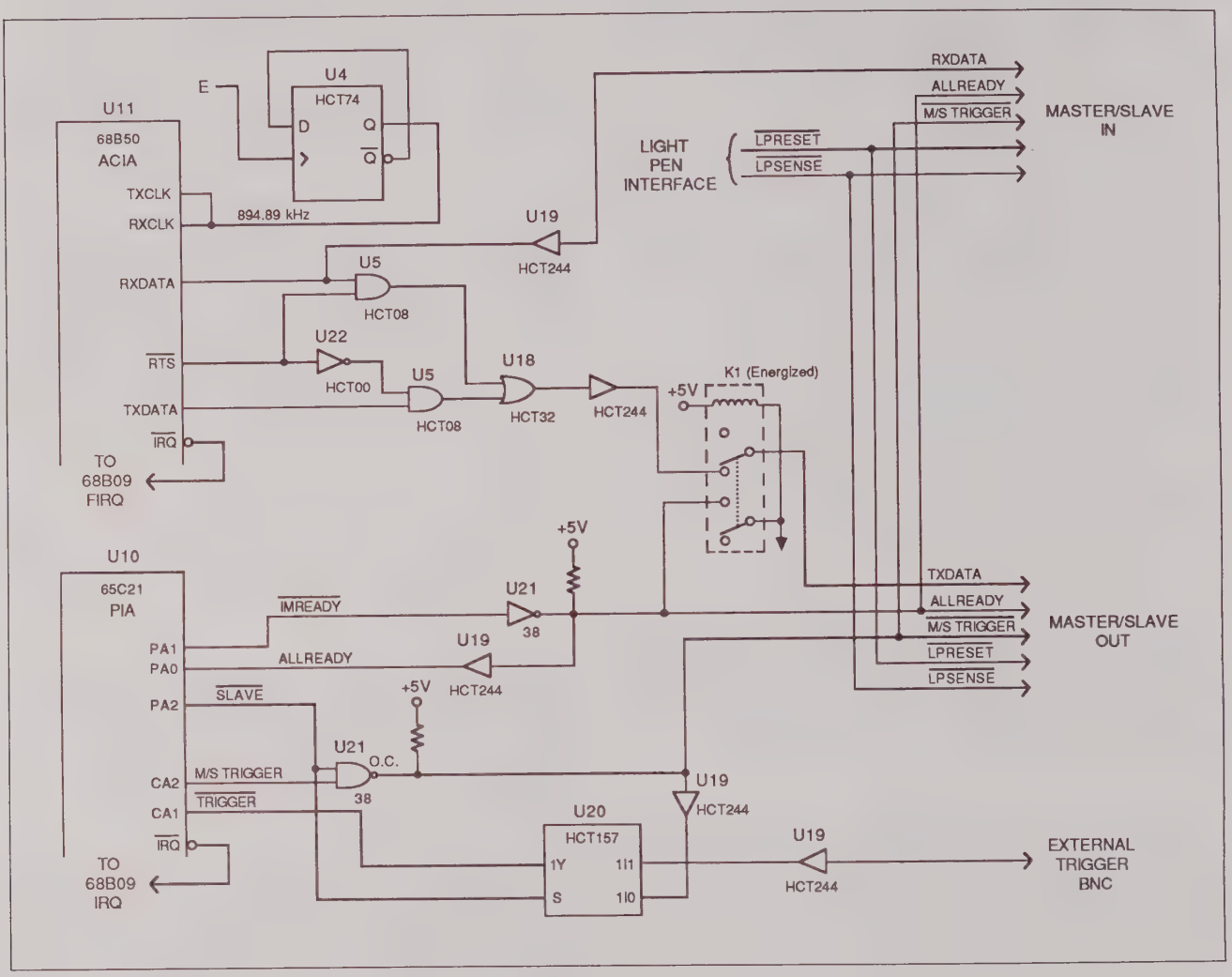


Figure 5-11. Master/Slave Interface Simplified Schematic

5.7.2 Control Signals

Bused control signals are managed by U10 (65C21 PIA). Bused outputs are driven by U21 (7438 open-collector NAND) and are buffered for input with U19 receivers.

The SLAVE (low true) signal selects the external trigger source:

- In slave units, the SLAVE signal is asserted. This causes multiplexer U20 to select the M/S TRIGGER (low true) signal for the trigger interrupt. Slaves are disabled from driving the M/S TRIGGER signal by the U21 NAND.
- In master or stand-alone units, SLAVE is negated and multiplexer U20 selects the External Trigger Input BNC for the trigger interrupt. This also enables the unit to drive the M/S TRIGGER signal via the U21 NAND.

The ALLREADY signal is wire-ORed so that it is negated whenever any unit in the master/slave loop has negated its IMREADY (low true) signal when receiving and processing data. When a slave unit is powered down, relay K1 provides a path to digital ground, simulating a negated IMREADY signal. This provides positive indication to other units on the master/slave loop that one of the units is not running. (Power-up software waits until all units have asserted their IMREADY signal.)

Assertion of M/S TRIGGER when the ALLREADY signal is false causes the slave units to reset to a known state. (Asserting M/S TRIGGER with ALLREADY true triggers the slaves.)

5.8 DIGITAL I/O

The digital input and digital output ports are two separate interfaces, even though they are on the same DB25 connector. A simplified schematic of the circuitry is shown in Figure 5-12.

Digital inputs are managed by U13 (74HCT373 transparent latch), which is decoded as a port on the microprocessor bus by PAL U2. U13 latches in the states of lines IN(0:7) whenever the INLATCH (low true) signal is asserted or the microprocessor reads the digital input port.

To cause the microprocessor to read the input lines, the INLATCH signal is also routed to the CB1 input of U10 (65C21 PIA), which is programmed to generate an interrupt on a falling edge.

Digital outputs are managed by port B of U10. The OUTPULSE (low true) signal on pin CB2 is asserted for about one E clock cycle (600nsec) after the microprocessor has written to the port B output lines OUT(0:7).

5.9 IEEE-488 BUS INTERFACE

The Model 707 has an IEEE-488 standard interface that allows the instrument to be programmed from a system controller. Commands can be sent over the bus to the instrument and data can be requested from the instrument.

The IEEE-488 interface is made up of U14, U15, and U16. U14 is a 9914A GPIA (general purpose interface adapter), while U15 and U16 are interface bus drivers.

The GPIA simplifies microprocessor interfacing to the IEEE-488 bus because many control sequences take place automatically. For example, when the microprocessor writes to the GPIA data output register, the handshake sequence is performed automatically. Without the GPIA chip, complex microprocessor routines would be required.

On the microprocessor side of the GPIA, data transmission is handled much like any other data bus transaction. Microprocessor data access is performed through the D0-D7 lines, while A0-A2 (the three least significant address lines) select among the 14 internal registers (seven read, seven write) of the GPIA. Chip selection is performed by the SELECT 9914 line.

The output of the GPIA is in standard IEEE-488 format. All of these lines are active low with approximately zero volts representing a logic one:

- Eight data lines (D1-D8).
- Three handshake lines (DAV, NRFD, NDAC).
- Five management lines (ATN, REN, IFC, SRQ, EOI).

The two IEEE-488 bus drivers, U15 and U16, bring the drive capability of the interface up to the requirements of the IEEE-488 standard, which includes provisions for up to 15 devices on the bus at once. The outputs of the bus drivers are connected to J25, a standard IEEE-488 connector.

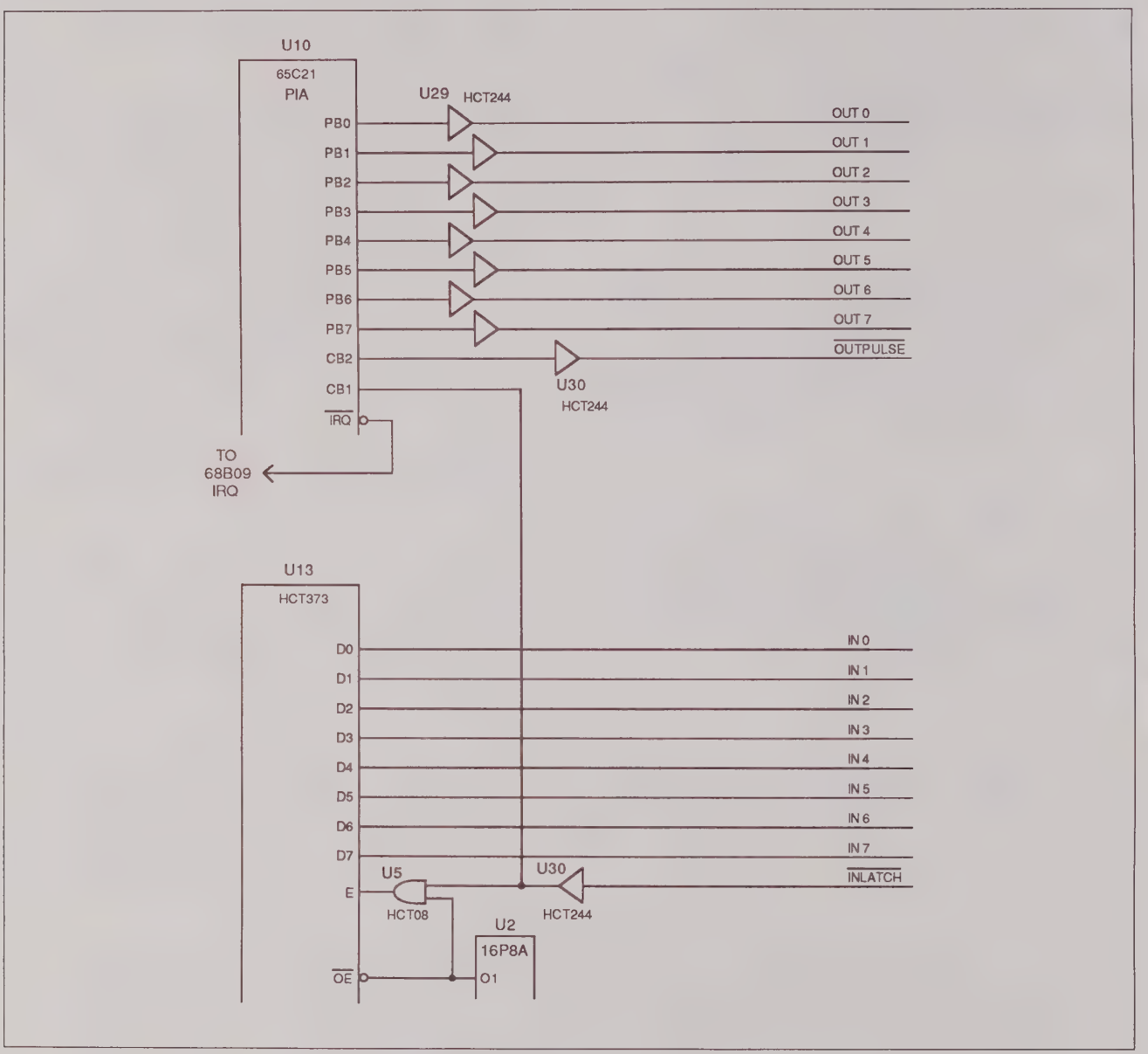


Figure 5-12. Digital I/O Interface Simplified Schematic

5.10 POWER SUPPLIES

The major components of the power section are two open-frame linear power supplies. A 5-volt supply powers all logic circuitry, including that on the matrix cards. A 6-volt supply drives the front panel display and relay coils on the matrix cards.

Sources for the display and relay coils are separated to reduce noise on the coils induced by multiplexing the display. This is done with an additional voltage regulator (mounted above the 6-volt supply) that gets its input from the unregulated voltage of the power supply.

The 6-volt outputs are distributed to the backplane board for the matrix cards and to the display board. The 5-volt supply output is routed through the digital board and then via ribbon cables to the display and backplane boards.

The primary sides of the two power supplies are connected to the line voltage selector switch on the rear panel through a barrier strip. This switch selects between two primary voltage ranges by connecting the two primary windings of each power supply either in parallel (115V) or in series (230V).

The rear panel fan is also connected to the line voltage switch. The fan is always in parallel with one and only one primary winding of the power supplies, so that it receives the correct voltage regardless of the switch setting.

SECTION 6
Maintenance

6.1 INTRODUCTION

This section contains information necessary to maintain and troubleshoot the Model 707 Switching Matrix. Handling and cleaning procedures are also included.

WARNING

The servicing procedures in this section are intended only for qualified electronics service personnel. Do not attempt to perform these procedures unless you are qualified to do so. Some of the procedures may expose you to potentially lethal voltages (>30V RMS) that could result in personal injury or death if normal safety precautions are not observed.

The section is outlined as follows:

6.2 **Line Voltage Selection:** Provides the procedure for setting the instrument operating voltage.

6.3 **Fuse Replacement:** Gives the procedure for replacing the line fuse located on the rear panel.

6.4 **Fixed Rack Installation:** Lists the installation instructions for a fixed rack mount kit for a Model 707.

6.5 **Disassembly:** Covers the procedure for disassembling the instrument, including circuit board removal.

6.6 **Battery Replacement:** Outlines the procedure for replacing the lithium battery.

6.7 **Static-sensitive Devices:** Covers precautions necessary when handling static-sensitive parts within the instrument.

6.8 **Mainframe Troubleshooting:** Outlines troubleshooting procedures for the Model 707.

6.9 **Relay Test Software:** Describes operation of software used to check the functionality of relay cards installed in Model 707 units.

6.10 **Cleaning:** Gives the procedure for cleaning the backplane board and the fan filter.

6.2 LINE VOLTAGE SELECTION

The Model 707 can be operated from either 105-125V or 210-250V, 50 or 60Hz sources. It can be rewired at the factory for the 90-110V and 180-220V ranges. The unit was shipped from the factory set for the operating voltage that corresponds to the one normally available in your area. The appropriate box on the rear panel (see Figure 6-1) is marked to indicate this range. The position of the switch indicates the selected line voltage. To change the line voltage proceed as follows.

WARNING

Disconnect the Model 707 from the power line and all other sources.

1. Locate the line voltage switch on the rear panel. Referring to Figure 6-1, place the switch in the correct position: to the right for low line voltage (90 to 125V) or to the left for high line voltage (180 to 250V).
2. Install a fuse consistent with the operating voltage, as described in paragraph 6.3.

CAUTION

The correct fuse type must be used to maintain proper instrument protection.

3. Mark the appropriate box on the rear panel for the selected line voltage. (Use Freon® or a similar fluid to remove any old marks.)

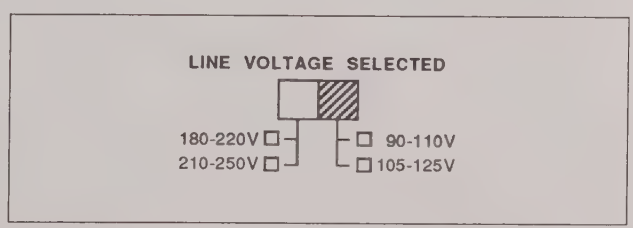


Figure 6-1. Line Voltage Switch

6.3 FUSE REPLACEMENT

The line fuse, located on the rear panel, protects the power line input of the instrument. Use the following procedure to replace the fuse, if necessary.

WARNING
Disconnect the instrument from the power line and other equipment before replacing the fuse.

1. With the power off, place the end of a flat-bladed screwdriver into the slot in the rear panel fuse holder. Press in gently and rotate the fuse holder approximately one-quarter turn counterclockwise. Release pressure on the holder and allow the internal spring to push the carrier and fuse out of the holder.
2. Separate the fuse from the carrier by carefully pulling the two apart.
3. Using an ohmmeter, check the fuse for continuity. A good fuse will show low resistance, while a blown fuse will read high (essentially infinite) resistance.
4. If the old fuse is defective, replace it with the type recommended in Table 6-1.

CAUTION
Do not use a fuse with a higher rating than specified, or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the problem before resuming operation of the unit.

5. Install the new fuse, located in the fuse carrier, by reversing the above procedure.

Table 6-1. Line Fuse Values

Line Voltage Range	Fuse Rating	Keithley Part No.
90-110V or 105-125V	2A, slow blow, 250V, 3AG	FU-25
180-220V or 210-250V	1A, slow blow, 250V, 3AG	FU-10

6.4 FIXED RACK INSTALLATION

Table 6-2 lists the necessary hardware for a fixed mounting of a Model 707 in a 19″ wide rack (24 to 30″ deep). Verify that all parts are available before beginning the installation procedure.

Table 6-2. Fixed Rack Parts

Item	Description	Keithley Part No.	Qty.
A	Chassis Support (left)	707-321	1
B	Chassis Support (right)	707-322	1
C	Nut, #10-32 Captive	FA-148	4
	Bracket Kit consisting of:	BR-31	1
D	Rear Support Bracket	—	2
E	Spacer Bar	—	2
F	Nut Bar	—	4
G	Screw, #10-32 × ½″ Phil. Binder Hd.	—	12

Rack Preparation

1. Select a position in the rack. In most cases, the weight of the Model 707 dictates a position in the lower half of the rack. The Model 707 will take up 14″ of vertical space.
2. Referring to Figure 6-2, install two captive nuts (item C) on each front rack flange at holes 11-3/8″ and 13-1/8″ from the top of the selected space.
3. Loosely attach a nut bar (item F) to each rear rack flange with two binder head screws (item G). See Figure 6-3. Mount the nut bars with the outer holes at the same level as the captive nuts. Note that the hole pattern on the nut bar is not symmetrical.

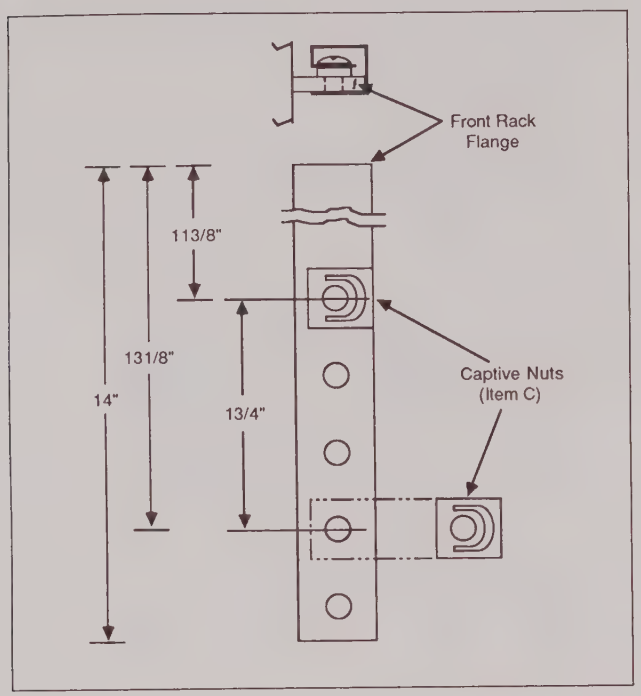


Figure 6-2. Captive Nut Installation

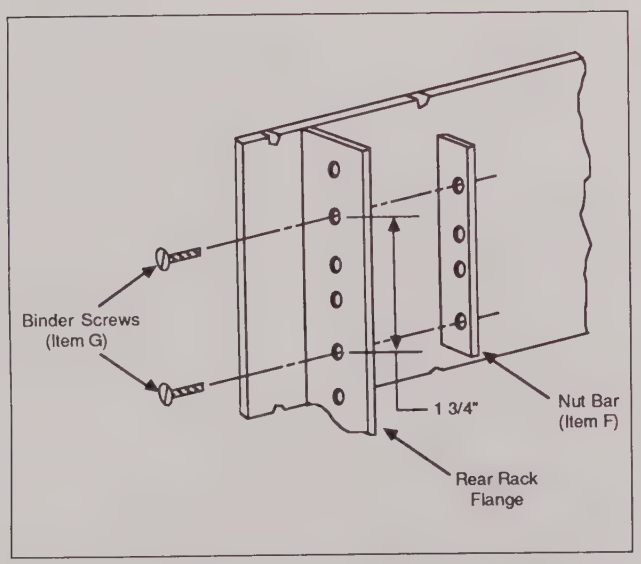


Figure 6-3. Nut Bar on Flange

Chassis Support Preparation

4. Place a rear support bracket (item D) on the left chassis support (item A) and temporarily install the two pieces in the rack by sliding them apart until their flanged ends fit as shown in Figure 6-4. Note which holes will be used to attach the two pieces together.
5. Use a spacer bar, nut bar, and two binder head screws (items E, F, and G) to loosely attach each rear support bracket to a chassis support. Figure 6-5 shows the left side support.

Chassis Support Mounting

6. Reinstall the chassis support assemblies in the rack and secure them to the captive nuts with binder head screws. Also tighten the binder screws at the rear rack flange.
7. Tighten the screws attaching the two pieces of the chassis support assemblies.

Mainframe Installation

8. Lift the Model 707 mainframe onto the chassis supports and slide it into the rack.
9. The mainframe can be secured to the front rack flanges with user-supplied captive nuts and binder head screws (four each).

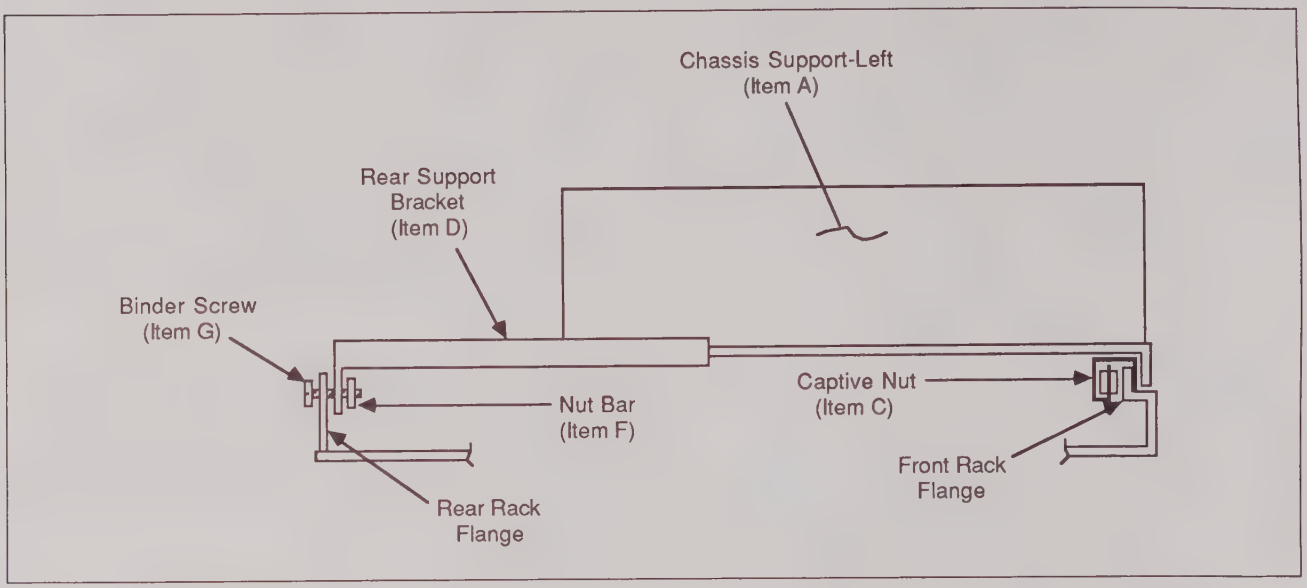


Figure 6-4. Chassis Support Sizing

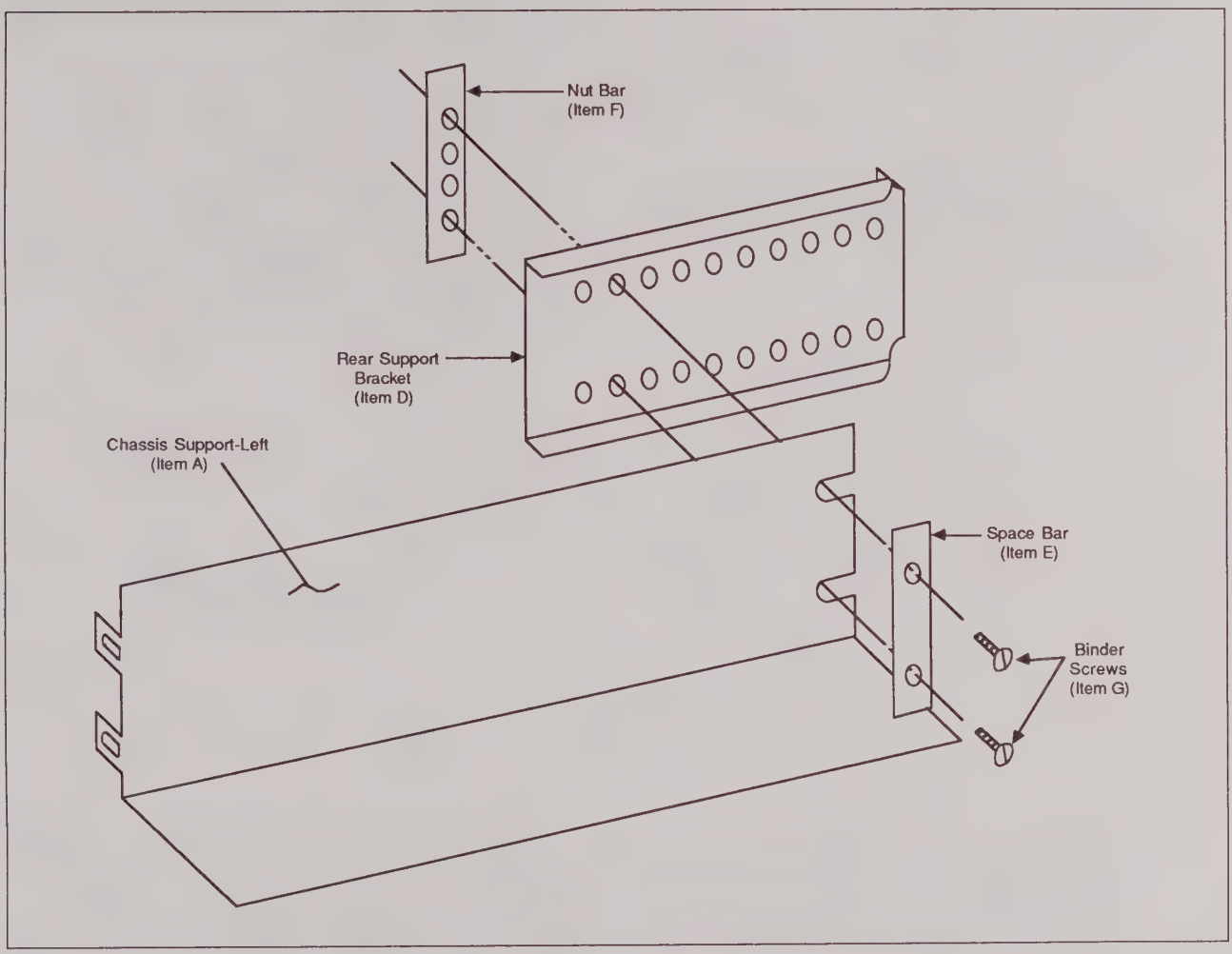


Figure 6-5. Chassis Support Assembly

6.5 DISASSEMBLY

If it is necessary to troubleshoot the instrument or replace a component, use the following disassembly procedure.

WARNING

Before disassembly, disconnect the line cord, ensure no voltage is applied from user circuits, and remove all plug-in cards from the instrument.

1. With the Model 707 on a bench, remove the front panel as follows:

A. Place a thin book or other support under the unit to slightly raise the bottom edge of the front panel off the bench surface.

B. Remove the four pan-head screws that secure the right and left handle mounting brackets to the side covers. Figure 6-6 shows a view of the right side.

C. Remove the three flat-head screws securing each side of the front panel to the right and left side covers.

D. Gently pull the front panel away from the mainframe. It may be necessary to loosen the two pan-head screws holding the backplane support bracket.

E. Swing the front panel to the left and rest it on its edge as shown in Figure 6-7.

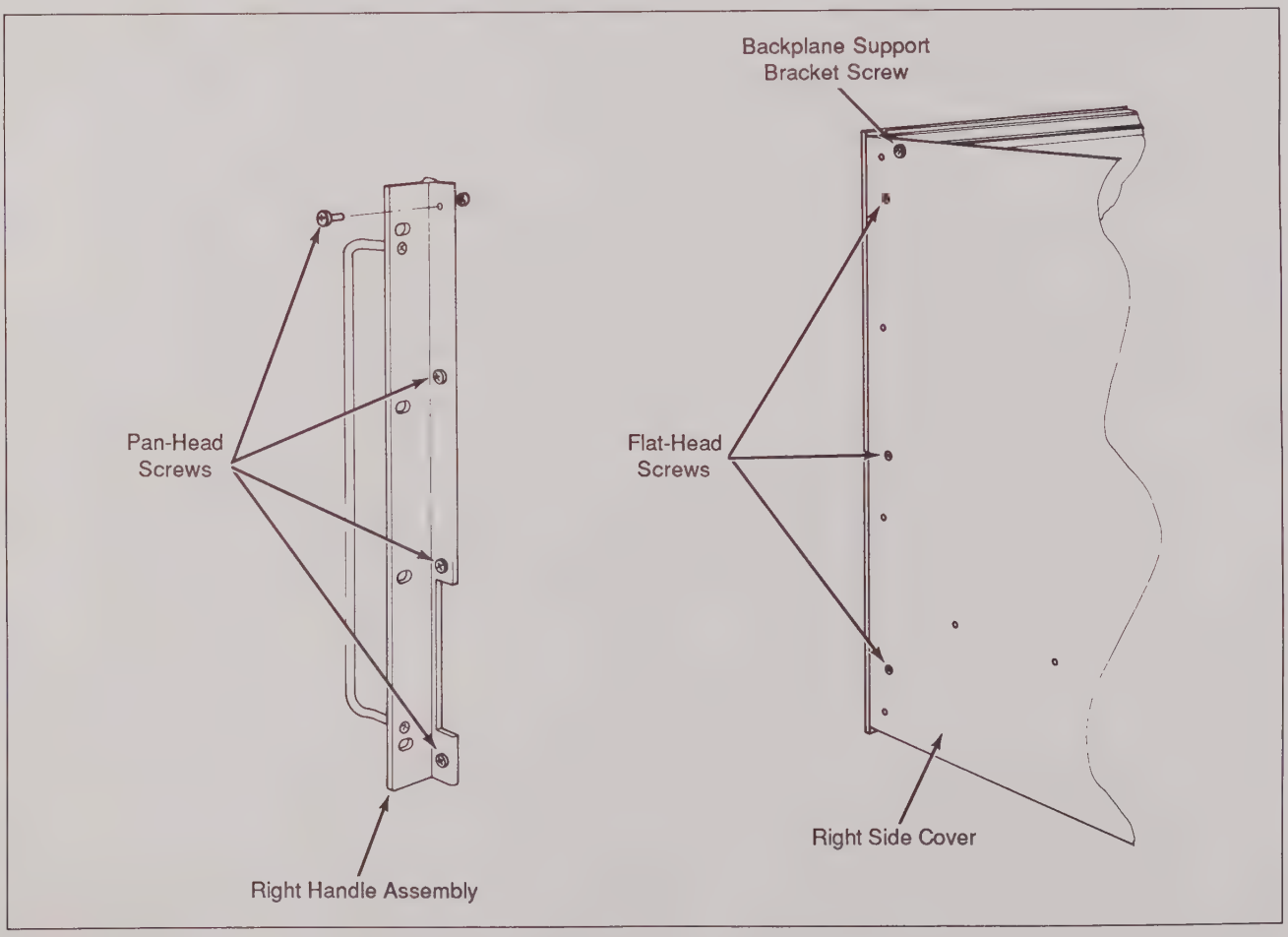


Figure 6-6. Right Side View of Disassembly

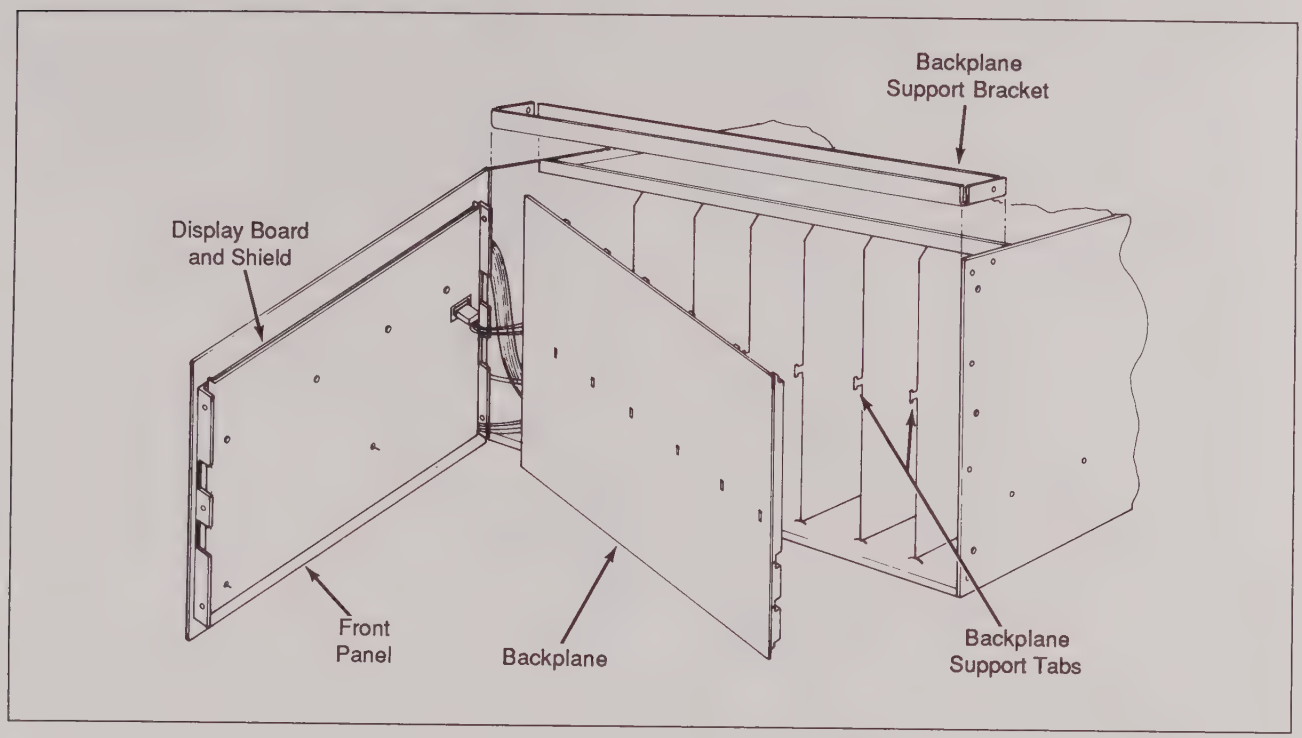


Figure 6-7. Front View of Disassembly

2. As shown in Figure 6-8, remove the left side cóver:
   A. Remove the ten pan-head screws securing the left side cover, including the one previously loosened in step 1D.
   B. Pull the side cover off its support tabs.
3. Remove the display board as follows:
   A. Unplug the following connections:

      P32—Digital board connection to light pen connector on front panel.

      P34—Digital board ribbon cable connection to display board.

      P36—Display board connection to voltage regulator board
   B. Disconnect the plug between the power switch on the front panel and the terminal strip in front of the digital board.
   C. Remove the four screws securing the display board shield and display board to the front panel.
4. Remove the backplane board as follows:

CAUTION

Avoid touching the board surface. Contamination can result in degraded matrix card performance. If contamination occurs, clean the board as described in paragraph 6.10.

   A. Remove the backplane support bracket shown in Figure 6-7.
   B. Unplug the following connections:

      P33—Digital board ribbon cable connection to backplane board.

      P33—Backplane board connection to 6-volt power supply.
   C. Remove the grounding wires from the grounding stud on the rear panel.
   D. Lift the backplane board by its edges off the backplane support tabs.
5. Referring to Figure 6-8, remove the digital board as follows:

A. On the Model 707 rear panel, pull off the Relay Test connector (P24). Also unscrew the two black stand-offs from the IEEE-488 connector (J25).
B. On the digital board, disconnect the following plugs (if not previously removed):

P29—Connector to External Trigger and Matrix Ready jacks.
P30—Ribbon cable connector to Digital I/O port.
P31—Connector to 5-volt power supply.
P32—Connector to light pen connector on front panel.
P33—Ribbon cable connector to backplane board.
P34—Ribbon cable connector to display board.

C. Remove the five screws securing the digital board to the mainframe and lift out the board.

6. Reverse the above procedure to re-assemble the instrument.

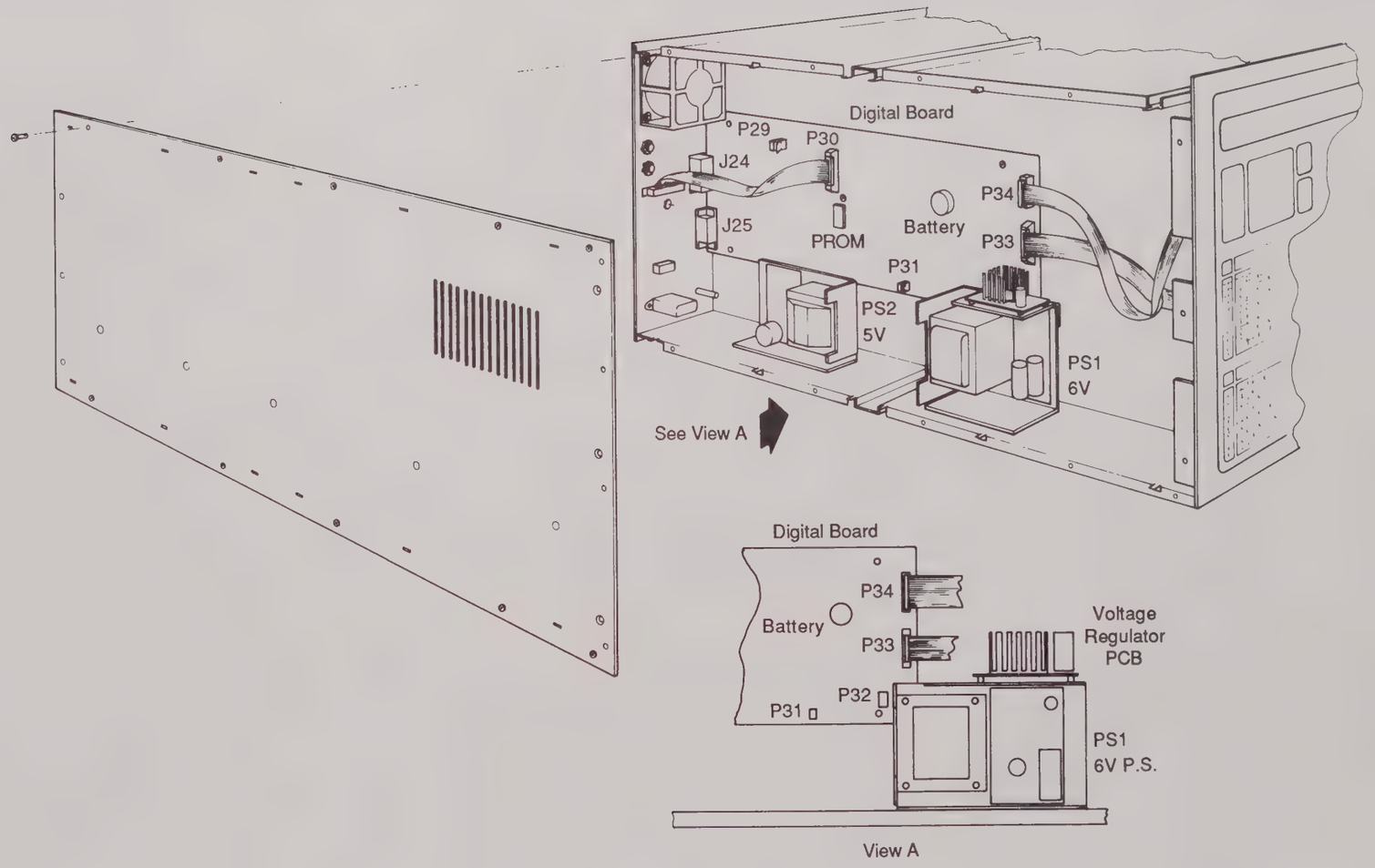


Figure 6-8. Left-Side View of Disassembly

6.6 BATTERY REPLACEMENT

When line power to the Model 707 is turned off, the lithium battery on the digital board provides backup power to the memory in which setups and parameters are stored. The battery has enough capacity to maintain data for one year of continuous power off, or two years if the Model 707 is powered on for 12 hours every day. The battery by itself has a shelf life of eight years. Although the Model 707 will operate without a battery, it will not retain any setups or parameters when turned off and will power up in random conditions.

The battery may be replaced with any CR2450 lithium coin cell. It can also be ordered from Keithley Instruments (part number BA-44), as discussed in Section 7 of this manual.

Replacement of the lithium battery is normally a safe procedure as long as these safety precautions are followed.

WARNING
The precautions below must be followed to avoid possible personal injury.

1. Wear safety glasses or goggles when working with lithium bateries.
2. Do not short the battery terminals together.
3. Do not incinerate or otherwise expose to excessive heat (>60°C).
4. Keep lithium batteries away from all liquids.
5. Do not recharge lithium batteries.
6. Observe proper polarity when inserting battery into holder.

Replace the battery as follows:

1. Turn off the power and remove the line cord from the Model 707.
2. Remove the left handle and side panel. (See paragraph 6.5.)
3. The lithium battery is on the digital board, as previously shown in Figure 6-8. Pry the battery out of its holder using a non-metallic tool.

WARNING
Do not use a metal tool to pry out the battery as you could short its terminals.

4. Install the new battery, taking care to observe proper polarity as stamped on the battery holder.
5. Reinstall the left side panel and handle.
6. Reinstall the power line cord and turn on the Model 707. It will power up in random conditions, such as make/break and break/make on the same rows.
7. Select the FACTORY INIT menu item to restore factory default conditions.

6.7 STATIC-SENSITIVE DEVICES

CMOS devices are designed to operate at high impedance levels for lower power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices if they are not handled properly. Use the precautions below when handling static-sensitive devices:

NOTE
Since the many CMOS devices installed in the Model 707 are not denoted in this manual, all ICs and transistors should be handled as static-sensitive devices.

1. Transport such devices only in containers designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Always leave the devices in question in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must also be properly grounded to the bench or table.
5. Use only anti-static type de-soldering tools.
6. Use only soldering irons with properly grounded tips.
7. Once the device is installed on the PC board, it is usually adequately protected, and normal handling can resume.

6.8 MAINFRAME TROUBLESHOOTING

This troubleshooting information is intended for qualified personnel having a basic understanding of digital and analog circuitry. The individual should also be experienced at using common test equipment, as well as ordinary

troubleshooting procedures. The information has been written to assist in isolating a defective circuit or circuit section. Isolation of the specific component is left to the technician.

Note that schematic diagrams and component layout drawings are located at the end of Section 7. Also, refer to Section 5 for an overview of operating principles.

6.8.1 Recommended Test Equipment

Success in troubleshooting equipment like the Model 707 depends not only on the skill of the technician, but also on the use of accurate, reliable test equipment. Table 6-3 lists the minimum recommended equipment for troubleshooting. Other equipment, such as logic analyzers, could also be helpful.

Table 6-3. Recommended Troubleshooting Equipment

Description	Application
DMM (Keithley 196)	Measure dc voltage.
Dual-trace, triggered sweep oscilloscope, dc to 50MHz	Check clock and logic pulses.

6.8.2 Power-up Self-test

As described in Section 3, the Model 707 performs a series of tests on power-up. Individual tests in this series that can be used for troubleshooting a Model 707 include:

- ROM test—A checksum test of ROM. Test failure is indicated by a ROM FAIL error message.
- RAM test—A read/write test of battery backed-up CMOS RAM. Test failure is indicated by a RAM FAIL error message.
- Display test—A visual test of the front panel displays. Check for all LEDs and indicators being lit.

These three tests can also be performed from the front panel through a menu selection (SELF TEST) or over the IEEE-488 bus with the command J0 (Perform Self-test).

6.8.3 Power Supply Checks

All power supply voltages should be checked first to make sure they are within the required limits. If the various operating voltages are not within the limits, troubleshooting the remaining circuitry can be quite difficult.

Table 6-4 outlines the voltages that should be checked. In addition to the usual checks with a voltmeter, it is a good idea to check the supplies with an oscilloscope to make sure that no noise or ringing is present.

6.8.4 Digital Board Checks

Tables 6-5 through 6-8 list the procedures to check circuitry on the digital board, including the microcomputer, relay control circuitry, display interface, and digital I/O port.

Procedures for testing the light pen and master/slave interface options are listed in Tables 6-9 and 6-10.

The waveforms described in the troubleshooting tables are present with power-up default conditions (idle state), unless otherwise indicated. To view some of the waveforms, it will be helpful to run a program loop. Refer to the programs of Figure 6-9 when directed by the procedure.

NOTE

If the ROM (U7) must be replaced for any reason, restore the Model 707 to factory default conditions with a menu selection (FACTORY INIT) or the device-dependent command R0.

Table 6-4. Power Supply Checks

Step	Item/Component	Signal	Comments
1	PS2	5.15Vdc ±1% (0.05V)	Measure and adjust logic voltage at power supply.
2	PS1	6Vdc ±2% (0.12V)	Measure and adjust relay coil voltage at power supply.
3	Voltage Regulator PCB	6Vdc ±7% (0.42V)	Measure front panel display voltage at voltage regulator board, not adjustable.

6.6 BATTERY REPLACEMENT

The lithium battery on the digital board, which saves the parameters and relay setups stored in RAM when line power is off, should last for about two years of normal use. (It has a 5-year shelf life.) Although the Model 707 will operate without a battery, it will not retain any parameters when turned off and will power up in random conditions.

The battery may be replaced with any CR2032 lithium coin cell. It can also be ordered from Keithley Instruments (part number BA-42), as discussed in Section 7 of this manual.

Replacement of the lithium battery is normally a safe procedure as long as these safety precautions are followed.

WARNING
The precautions below must be followed to avoid possible personal injury.

1. Wear safety glasses or goggles when working with lithium bateries.
2. Do not short the battery terminals together.
3. Do not incinerate or otherwise expose to excessive heat (>60°C).
4. Keep lithium batteries away from all liquids.
5. Do not recharge lithium batteries.
6. Observe proper polarity when inserting battery into holder.

Replace the battery as follows:

1. Turn off the power and remove the line cord from the Model 707.
2. Remove the left handle and side panel. (See paragraph 6.5.)
3. The lithium battery is on the digital board, as previously shown in Figure 6-8. Pry the battery out of its holder using a non-metallic tool.

WARNING
Do not use a metal tool to pry out the battery as you could short its terminals.

4. Install the new battery, taking care to observe proper polarity. (The + side faces you.)
5. Reinstall the left side panel and handle.
6. Reinstall the power line cord and turn on the Model 707. It will power up in random conditions, such as make/break and break/make on the same rows.
7. Select the FACTORY INIT menu item to restore factory default conditions.

6.7 STATIC-SENSITIVE DEVICES

CMOS devices are designed to operate at high impedance levels for lower power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices if they are not handled properly. Use the precautions below when handling static-sensitive devices:

NOTE
Since the many CMOS devices installed in the Model 707 are not denoted in this manual, all ICs and transistors should be handled as static-sensitive devices.

1. Transport such devices only in containers designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Always leave the devices in question in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must also be properly grounded to the bench or table.
5. Use only anti-static type de-soldering tools.
6. Use only soldering irons with properly grounded tips.
7. Once the device is installed on the PC board, it is usually adequately protected, and normal handling can resume.

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- Display test—A visual test of the front panel displays. Check for all LEDs and indicators being lit.

These three tests can also be performed from the front panel through a menu selection (SELF TEST) or over the IEEE-488 bus with the command J0 (Perform Self-test).

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Procedures for testing the light pen and master/slave interface options are listed in Tables 6-9 and 6-10.

The waveforms described in the troubleshooting tables are present with power-up default conditions (idle state), unless otherwise indicated. To view some of the waveforms, it will be helpful to run a program loop. Refer to the programs of Figure 6-9 when directed by the procedure.

NOTE

If the ROM (U7) must be replaced for any reason, restore the Model 707 to factory default conditions with a menu selection (FACTORY INIT) or the device-dependent command R0.

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2	PS1	6Vdc ±2% (0.12V)	Measure and adjust relay coil voltage at power supply.
3	Voltage Regulator PCB	6Vdc ±7% (0.42V)	Measure front panel display voltage at voltage regulator board, not adjustable.

Table 6-5. Microcomputer Checks

Step	Item/Component	Signal	Comments
1	PS2	5.15Vdc ±1% (0.05V)	Measure and adjust at power supply.
			The following digital board signals are referenced to digital common.
2	U6 pin 37	MPU Reset	Stays low 110-260msec on power-up, then goes high.
3	U6 pin 34	E clock	1.79MHz square wave for peripheral chips.
4	U9 pin 23	SELECT VIA	Low going pulses (1kHz).
5	U6 pins 8-23	Address bus (A0-A15)	Check for stuck bit.
6	U6 pins 24-31	Data bus (D0-D7)	Check for stuck bit.

Table 6-6. Relay Control Checks

Step	Item/Component	Signal	Comments
			The following digital board signals are referenced to digital common.
			See Figure 6-10 for waveforms of steps 8 through 10.
1	U9 pin 23	SELECT VIA	Low going pulses (1kHz).
2	U28 pin 5	CLRADDR	High logic pulse at start of each matrix card ID byte transfer sequence on power-up.
3	U28 pin 3	NEXTADDR	Low logic pulse before each byte transfer from matrix card on power-up.
4	U28 pin 6	IDDATA	Matrix card ID logic pulse train on power-up.
5	U12 pin 11	SELECT CARDSEL	Pair of low going pulse trains when program #1 is running.
6	U12 pin 16	STROBE	High logic pulse to strobe relay drivers on matrix card.
7	U12 pins 2,5,6,9,12,15	CARD(1-6)	Low logic pulse selects matrix card for data transfer sequence.
8	U24 pin 1	SELECT RELAYDATA	Low going pulse when program #1 is running.
9	U28 pin 7	CLK	Eight low-going pulses (1.79MHz square wave) after each SELECT RELAYDATA pulse.
10	U28 pin 18	RELAYDATA	Logic pulses to load relay drivers on matrix card.

Table 6-7. Display Interface Checks

Step	Item/Component	Signal	Comments
			The following digital board signals are referenced to digital common. See Figure 6-11 for waveforms of steps 2 through 6.
1	U9 pin 23	SELECT VIA	Low going pulses (1kHz).
2	U9 pin 18	FPCLK	Base frequency of 895kHz with ten sets of pulses every 1msec.
3	U18 pin 6	DISPCLK	Base frequency of 895kHz with nine sets of pulses every 1msec.
4	U18 pin 3	KEYCLK	Base frequency of 895kHz with one set of pulses every 1msec.
5	U23 pin 6	DISPDATA	See Figure 6-11.
6	U23 pin 2	KEYDATA	See Figure 6-11.

Table 6-8. Digital I/O Checks

Step	Item/Component	Signal	Comments
			The following digital board signals are referenced to digital common.
1	U10 pin 23	SELECT PIA	Low going pulses (1kHz).
2	U10 pins 10-17	OUT(0-7)	Logic low when programmed low.
3	U10 pin 19	OUTPULSE	Low going pulses (600nsec) when program #2 is running.
4	U13 pin 1	SELECT DIG INPUT	Low going pulses (5kHz) when digital input is displayed.
5	U13 pins 3,4,7,8,13,14, 17,18	IN(0-7)	Logic high when port disconnected.

Table 6-9. Light Pen Checks

Step	Item/Component	Signal	Comments
			The following digital board signals are referenced to digital common.
1	U9 pin 23	SELECT VIA	Low going pulses (1kHz).
2	U23 pin 12	SENSEPULSE	Low going pulse (15μsec) when light pen is pointed at lit LED.
3	U23 pin 9	LPSWITCH	Low logic level when light pen button is pressed.
4	U9 pin 17	LPSENSE	High going pulse when light pen button is pressed and pen is pointed at an LED.
5	U9 pin 39	LPRESET	Multiple high going pulses when light pen button is pressed.

Table 6-10. Master/Slave Checks

Step	Item/Component	Signal	Comments
			The following digital board signals are referenced to digital common. When troubleshooting a single unit, loop a cable from Master/Slave Out to Master/Slave In of the same unit, then program unit as master.
1	U11 pins 3,4	RXCLK, TXCLK	895kHz square wave.
2	U11 pin 9	SELECT ACIA	Low going pulses with manual triggers.
3	U11 pins 2,6	RXDATA, TXDATA	Low going pulse pair with manual trigger.
4	U11 pin 7	FIRQ	Low going pulse with manual trigger.
5	U10 pin 23	SELECT PIA	Low going pulses (1kHz).
6	U10 pin 39	M/S TRIGGER	High going pulses when program #3 is running. (Triggering stops when Relay Step equals 100.)

Program #1

```
10  REMOTE 718
20  CLEAR 718
30  OUTPUT 718;''CA1X''  ! Close crosspoint A1
40  OUTPUT 718;''NA1X''  ! Open crosspoint A1
50  GOTO 30
60  END
```

Program #2

```
10  REMOTE 718
20  CLEAR 718
30  OUTPUT 718;''00X''   ! Set digital output to
                         zero
40  WAIT .1              ! Delay 0.1sec
50  GOTO 30
60  END
```

Program #3

```
10  REMOTE 718
20  CLEAR 718
30  OUTPUT 718;          ! Enable triggers on GET
    ''T2XF1X''
40  TRIGGER 718
50  GOTO 40              ! Triggering stops at 100
60  END
```

Figure 6-9. Troubleshooting Programs

6.8.5 Display Board Checks

To troubleshoot the display board, it is helpful to disassemble it from the front panel, then reconnect the power cable and ribbon cable with the display board on a bench.

A troubleshooting procedure is outlined in Table 6-11.

6.9 RELAY TEST SOFTWARE

The Relay Test software verifies the operation of relay cards designed for use in the Model 707. It is a functional test of the cards, not a performance test. The Relay Test program should be run to:

- Check relay operation of a new system configuration.
- Verify relay operation as part of daily, weekly, or monthly preventive maintenance.
- Isolate a suspected bad relay.

The program checks for open and closed crosspoint relays through connections made between card rows and the rear panel Relay Test connector of a stand-alone or master unit. The cards are tested one-by-one, mainframe-by-mainframe.

The software is supplied in two media formats:

- 5¼" diskette (Keithley P/N 707-851)—For an IBM PC or compatible with a Capital Equipment Corporation IEEE-488 interface. (PC-488-CEC is available from Keithley Instruments.)
- 3½" diskette (Keithley P/N 707-852)—For an HP Series 200 or 300 computer running HP BASIC 4.0.

Table 6-11. Display Board Checks

Step	Item/Component	Signal	Comments
			The following display board signals are referenced to digital common.
			When troubleshooting the LED array, check for these signals when the LED is lit (e.g., crosspoint A1).
1	U13 pin 12	Source driver	Card row A - Logic high for 9msec.
2	U3 pin 17	Sink driver	Card column 1 - Logic low.
			Segment displays:
3	U11 pins 6-12; U12 pins 5-12	Source drivers	Low going pulses (1kHz) with all segments lit.
4	U1 pins 4-7, 14-16; U2 pins 4-7, 14-17	Sink drivers	Low going pulses (1kHz).
			Front panel buttons:
5	U27 pins 1-6	Button columns	Logic high with a low going 1msec pulse.
6	U28 pins 3-5, 11-14	Button rows	Logic high with a low going 1msec pulse when button pressed.

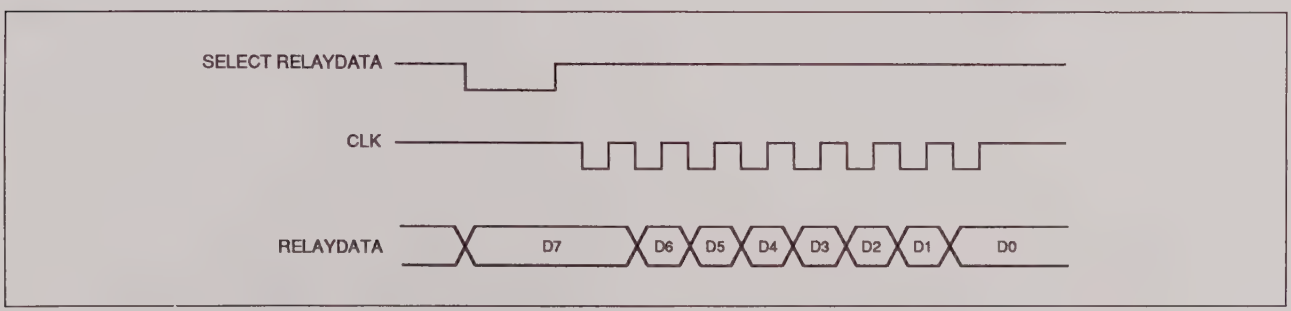


Figure 6-10. Relay Control Waveforms

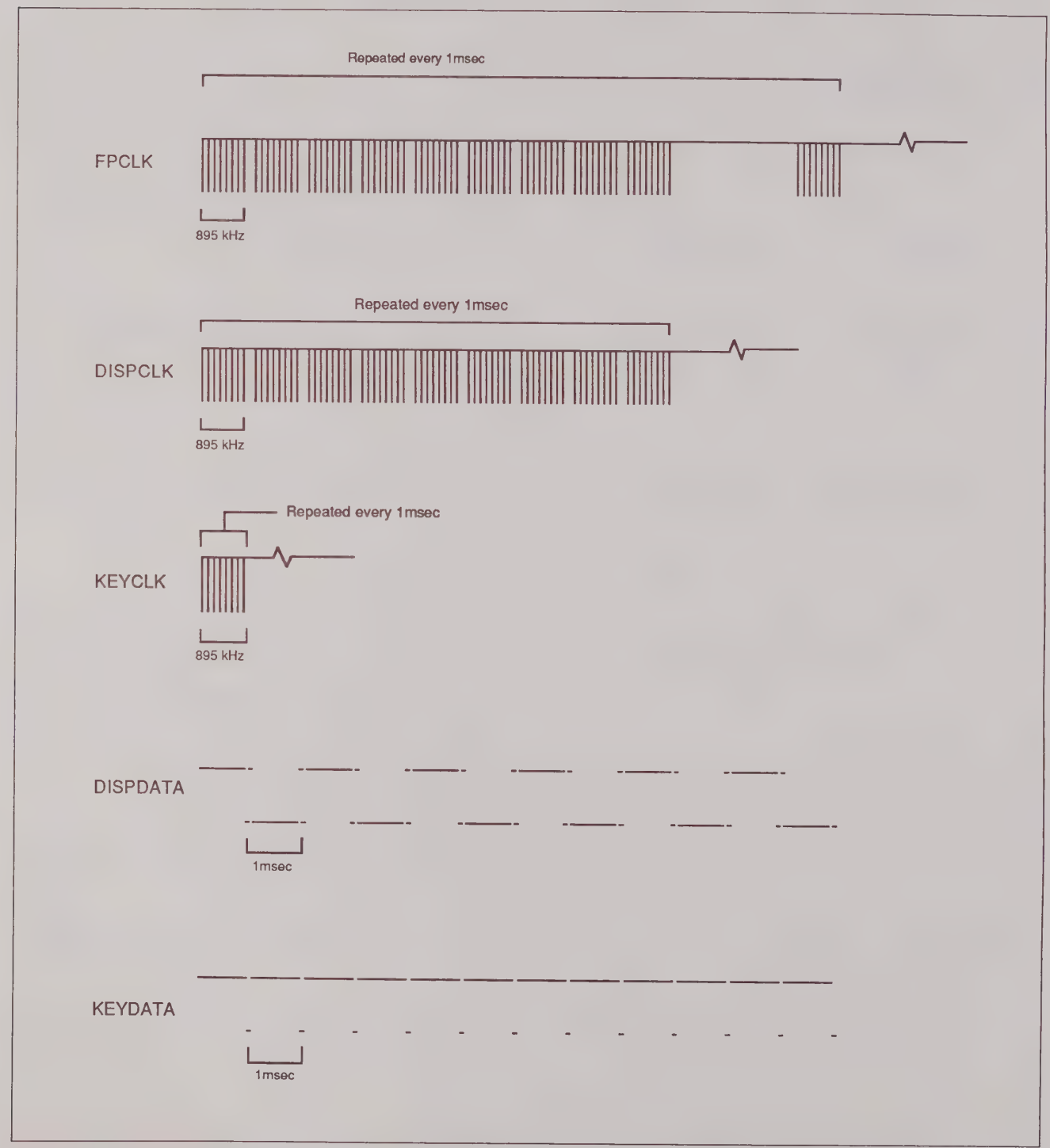


Figure 6-11. Display Interface Waveforms

6.9.1 Running the Program

Program operation is shown in the flowchart of Figure 6-12 and outlined below.

1. Start the Relay Test program on HP controllers by loading and running RELAYTEST from the 3½" disk. For an IBM PC or compatible with a CEC card, the 5¼" disk contains two files, one an executable file and the other a source file (written in Microsoft QuickBASIC). Type in RELAYTST to the appropriate disk drive prompt to start the program.
2. The program begins by displaying a header screen listing its revision and supported relay cards. Press the Continue (HP) or Enter (PC) key on the controller to continue.
3. You will be prompted to type in the IEEE-488 bus address of the Model 707. Be sure all units are powered up at this time.
4. The program checks for the number of units (1-5) and asks which mainframes you want to test.
5. The card configuration of the mainframe you selected is displayed. Choose which cards you want tested with a "Y/N" response. Although the cards are tested one-by-one, it might be advantageous to test like card models one after another so the wiring at the Relay Test connector does not change.
6. The next screen describes wiring between rows A and B of the card to be tested and the Relay Test connector of the stand-alone or master unit. These connections are shown in Section 4 of the appropriate card manual.

   It is necessary to remove all user connections between the card and test system, not just the row A and B connections. Do not remove master/slave loop cables.
7. The "707 Relay Test in Progress" message is displayed and the program checks for improper relay operation on the card. The front panel crosspoint display shows which relays are closed as the test steps through the crosspoints.
8. If the card passes, the program returns to a screen describing wiring for the next card to be tested (step 6). If a relay does not open or close on command, the program exits and displays an error message, such as:

   Found relay closed at row H, column 36

9. When all cards pass the test in a stand-alone system, the message "Test done. No errors detected" is displayed and the program exits. For a master/slave system, the program pauses and asks if you want to test the next mainframe. Steps 5 through 9 are repeated for the remaining units.

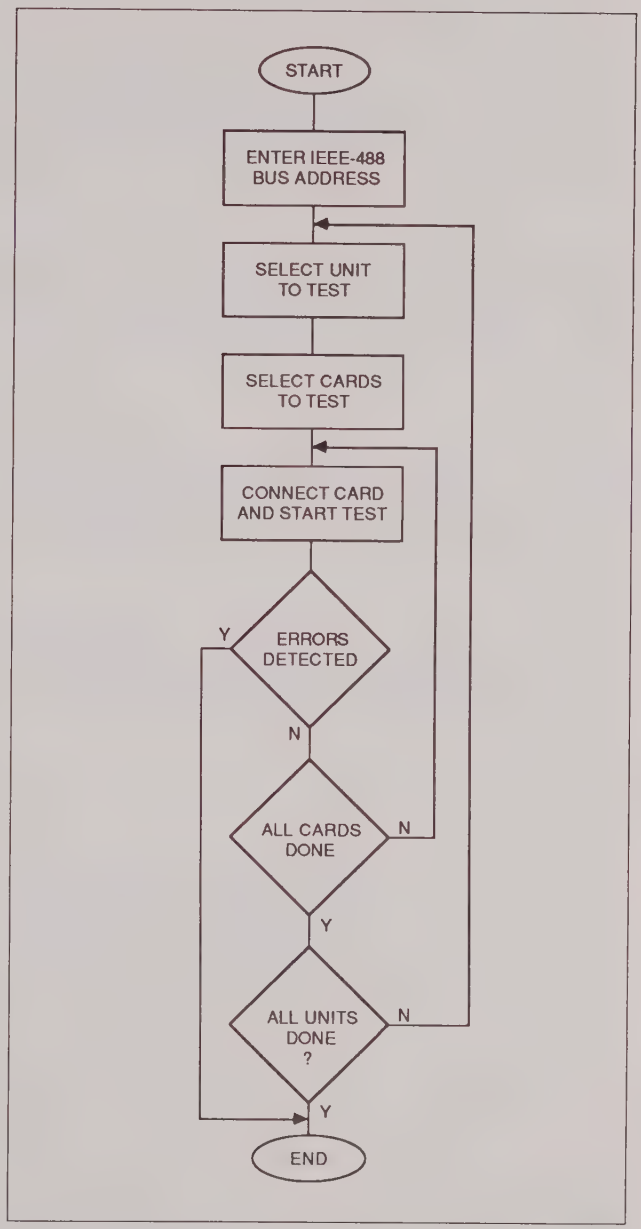


Figure 6-12. Operation of Relay Test Program

6.9.2 Analyzing Errors

When the Relay Test program detects a defective relay, it displays an error message and immediately exits. The message will be as specific as possible given the card configuration; it could identify one, two, or four suspected relays.

The error message "Found relay open at row A or row B, column 1" is an indication that the wiring between the card in slot 1 and the Relay Test connector might be incorrect. (The message would read column 13 when testing the card in slot 2, column 25 for slot 3, etc.)

If there is a short between the poles of a 2-pole relay (where one pole is tied to common), the Relay Test is able to detect the defective row only. This contact configuration is present on the Model 7073 and rows G and H of the Model 7072.

Row and column isolator relays, such as on the Model 7072, are more difficult to test. Isolators that remain closed are completely undetectable. If detected at all, isolators that remain open generate a crosspoint error message.

6.9.3 Using an Extender Card

To access circuitry on the plug-in relay cards of the Model 707, use a Model 7070 Universal Adapter Card. The Model 7070 must be configured as an extender card by placing the configuration jumper in the EXTEND position. See the Model 7070 Instruction Manual for complete details on using the card.

6.10 CLEANING

6.10.1 Backplane

Since matrix card rows are extended on the three analog backplanes of the Model 707 (as explained in Section 2), a contaminated backplane will degrade card isolation specifications. If an isolation problem exists, the backplane should be cleaned only after the isolation of each card has been tested according to the respective card manuals.

The following procedure is primarily intended to clean high impedance PC boards, such as the Model 707 backplane, but it can be used to clean all PC boards. To remove the backplane, refer to paragraph 6.5.

1. Handle the board by the edges only. Do not touch any board surfaces. When servicing, wear clean, white cotton gloves.
2. If making solder repairs on the board, use a flux that is rosin RMA based. Remove the flux from these areas when the repair is complete. Use Freon® TMS or TE, or the equivalent along with plenty of clean cotton swabs to remove the flux. Take care not to spread the flux to other areas of the board.
3. Once the flux has been removed, swab only the repaired area with methanol, then blow dry the board with dry nitrogen gas.
4. After cleaning, the board should be placed in a 50°C low humidity environment for several hours.

6.10.2 Fan Filter

The fan filter, which is located on the rear panel, keeps dirt from being drawn into the instrument by the internal cooling fan. The filter opening should be kept free of obstructions to ensure proper instrument cooling.

The filter should be checked periodically for dirt build-up, and cleaned or replaced, as necessary. Use the following procedure to clean or replace the filter.

1. Disconnect the line cord from the power line receptacle.
2. Grasp the filter holder, and pull it free of the rear panel.
3. Remove the filter element from the holder.
4. Soak the filter in a solution of warm water and mild detergent until clean. Rinse thoroughly in clean water, and allow the filter to dry completely before installation. If a new filter assembly is required, one may be obtained by ordering Keithley part number FL-6.

NOTE

Do not operate the instrument with the filter removed to avoid dirt build-up within the instrument.

5. If necessary, clean the fan guard with a damp cloth.
6. Install the filter element in the holder and snap the holder back onto the fan guard. The two tabs on the holder should be oriented at the right and left sides.

SECTION 7
Replaceable Parts

7.1 INTRODUCTION

This section contains replacement parts information, component location drawings, and schematic diagrams for the Model 707 Switching Matrix.

7.2 PARTS LIST

Electrical parts for the Model 707 circuit boards are integrated with the component layout drawings and schematic diagrams for the respective circuit boards. Parts are listed alphabetically in order of circuit designation.

A miscellaneous parts list is located at the end of this section.

7.3 ORDERING INFORMATION

Keithley Instruments maintains a complete inventory of all normal replacement parts. To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover of this manual for addresses.

When ordering parts, include the following:

1. Instrument model number
2. Instrument serial number
3. Part description
4. Circuit designation, if applicable
5. Keithley part number

7.4 FACTORY SERVICE

If the mainframe is to be returned to the factory for service, carefully pack it and include the following information:

1. Complete the service form located at the back of this manual and include it with the mainframe.
2. Advise as to the warranty status of the instrument (see the inside front cover of this manual for warranty information).
3. Write ATTENTION REPAIR DEPARTMENT on the shipping label. Note that it is not necessary to return matrix cards with the mainframe.

7.5 COMPONENT LOCATION DRAWINGS AND SCHEMATIC DIAGRAMS

Component location drawings and schematic diagrams for the various circuit boards can be found on the following pages arranged as follows:

Board	Component Layout	Schematic Diagram
Digital	707-100	707-106
Display	707-110	707-116
Backplane	707-120	707-126
Voltage Regulator	707-160	707-166

MODEL 707 DIGITAL BOARD PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART No.
BT1	BATTERY	BA-42
C1..C30	CAP,.01uF,20%,50V,CERAMIC	C-365-.01
C31,C32	CAP,15pF,10%,1000V,CERAMIC	C-64-15P
C33..C90	CAP,270pF,20%,100V,CERAMIC/FERRITE	C-386-270P
C91	CAP,3.3UF,10%,16V,ALUM ELEC	C-321-3.3
C92	CAP,10uF,-20+100%,25V,ALUM ELEC	C-314-10
CR18,CR19	DIODE,SILICON,1N4148 (DO-35)	RF-28
CR1..CR17	DIODE,BRIDGE,VM18	RF-52
J22,J23	CONN,8 PIN CIRCULAR DIN	CS-589
J24	CONN,6 PIN OPEN END HEADER	CS-587-6
J25	CONN,RIGHT ANGLE,24 PIN	CS-507
J29	CONN,MALE,3 PIN	CS-288-3
J30,J33	CONN,MALE HEADER 26-PIN	CS-322-26
J3	CONN,MALE,2 PIN	CS-288-2
J32	CONN,MALE,4 PIN	CS-288-4
J34	CONN,HEADER STRAIGHT SOLDER PIN	CS-368-20
K1	RELAY,MINIATURE (DPDT)	RL-98
P24	CONN,6 PIN	CS-588-6
R10,R15..R19,R21	RES,4.7K,5%,1/4W,COMPOSITION OR FILM	R-76-4.7K
R1..R7,R42	RES,3.3K,5%,1/4W,COMPOSITION OR FILM	R-76-3.3K
R20,R22,R23,R33	RES NET,100,2%,.25W	TF-102-3
R24..R31,R38,R40		
R32,R37,R41		
R34	RES,20K,1%,1/8W,METAL FILM	R-88-20K
R35	RES,63.4K,1%,1/8W,METAL FILM	R-88-63.4K
R36	RES,,1M,5%,1/4W,COMPOSITION OR FILM	R-76-1M
R39	RES,10.10%,2W,COMPOSITION	R-3-10
R43..R45	RES NET,47,5%,.14W	TF-64
R46..R49		
R8,R9,R11..R14	RES,100,5%,1/4W,COMPOSITION OR FILM	R-76-100
U1	IC,OCTAL 10 INPUT GATE ARRAY,PAL16P8A	IC-573
U10	IC,PERIPHERAL INTERFACE ADAPTER 65C21	LSI-61
U11	IC,ACIA,68B50	LSI-72
U12	IC,OCTAL FLIP FLOP,74HCT374	IC-397
U13	IC,OCTAL LATCH,74HCT373	IC-549
U14	IC,GPIB ADAPTER,9914A	LSI-49
U15	OCTAL INTERFACE BUS TRANSCEIVER	IC-298
U16	OCTAL INTERFACE BUS TRANSCEIVER	IC-299

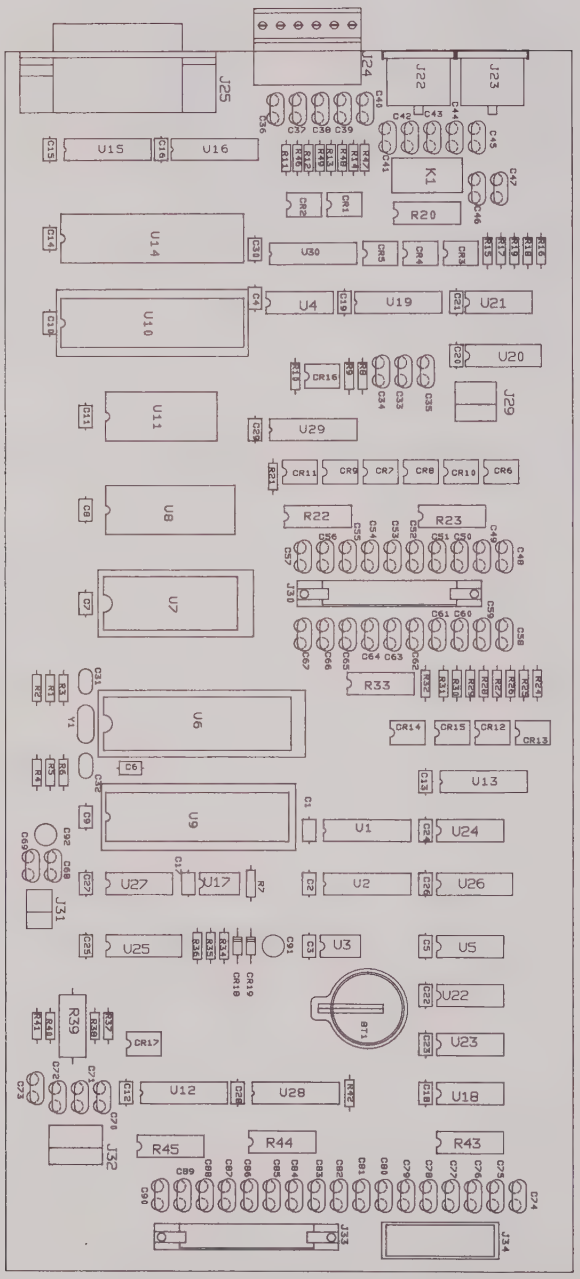
MODEL 707 DIGITAL BOARD PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART No.
BT1	BATTERY	BA-44
C1..C30	CAP,.01uF,20%,50V,CERAMIC	C-365-.01
C31,C32	CAP,15pF,10%,1000V,CERAMIC	C-64-15P
C33..C90	CAP,270pF,20%,100V,CERAMIC/FERRITE	C-386-270P
C91	CAP,3.3UF,10%,16V,ALUM ELEC	C-321-3.3
C92	CAP,10uF,-20+100%,25V,ALUM ELEC	C-314-10
CR18,CR19	DIODE,SILICON,1N4148 (DO-35)	RF-28
CR1..CR17	DIODE,BRIDGE,VM18	RF-52
J22,J23	CONN,8 PIN CIRCULAR DIN	CS-589
J24	CONN,6 PIN OPEN END HEADER	CS-587-6
J25	CONN,RIGHT ANGLE,24 PIN	CS-507
J29	CONN,MALE,3 PIN	CS-288-3
J30,J33	CONN,MALE HEADER 26-PIN	CS-322-26
J3	CONN,MALE,2 PIN	CS-288-2
J32	CONN,MALE,4 PIN	CS-288-4
J34	CONN,HEADER STRAIGHT SOLDER PIN	CS-368-20
K1	RELAY,MINIATURE (DPDT)	RL-98
P24	CONN,6 PIN	CS-588-6
R10,R15..R19,R21	RES,4.7K,5%,1/4W,COMPOSITION OR FILM	R-76-4.7K
R1..R7,R42	RES,3.3K,5%,1/4W,COMPOSITION OR FILM	R-76-3.3K
R20,R22,R23,R33	RES NET,100,2%,.25W	TF-102-3
R24..R31,R38,R40		
R32,R37,R41		
R34	RES,20K,1%,1/8W,METAL FILM	R-88-20K
R35	RES,63.4K,1%,1/8W,METAL FILM	R-88-63.4K
R36	RES,,1M,5%,1/4W,COMPOSITION OR FILM	R-76-1M
R39	RES,10.10%,2W,COMPOSITION	R-3-10
R43..R45	RES NET,47,5%,.14W	TF-64
R46..R49		
R8,R9,R11..R14	RES,100,5%,1/4W,COMPOSITION OR FILM	R-76-100
U1	IC,OCTAL 10 INPUT GATE ARRAY,PAL16P8A	IC-573
U10	IC,PERIPHERAL INTERFACE ADAPTER 65C21	LSI-61
U11	IC,ACIA,68B50	LSI-72
U12	IC,OCTAL FLIP FLOP,74HCT374	IC-397
U13	IC,OCTAL LATCH,74HCT373	IC-549
U14	IC,GPIB ADAPTER,9914A	LSI-49
U15	OCTAL INTERFACE BUS TRANSCEIVER	IC-298
U16	OCTAL INTERFACE BUS TRANSCEIVER	IC-299

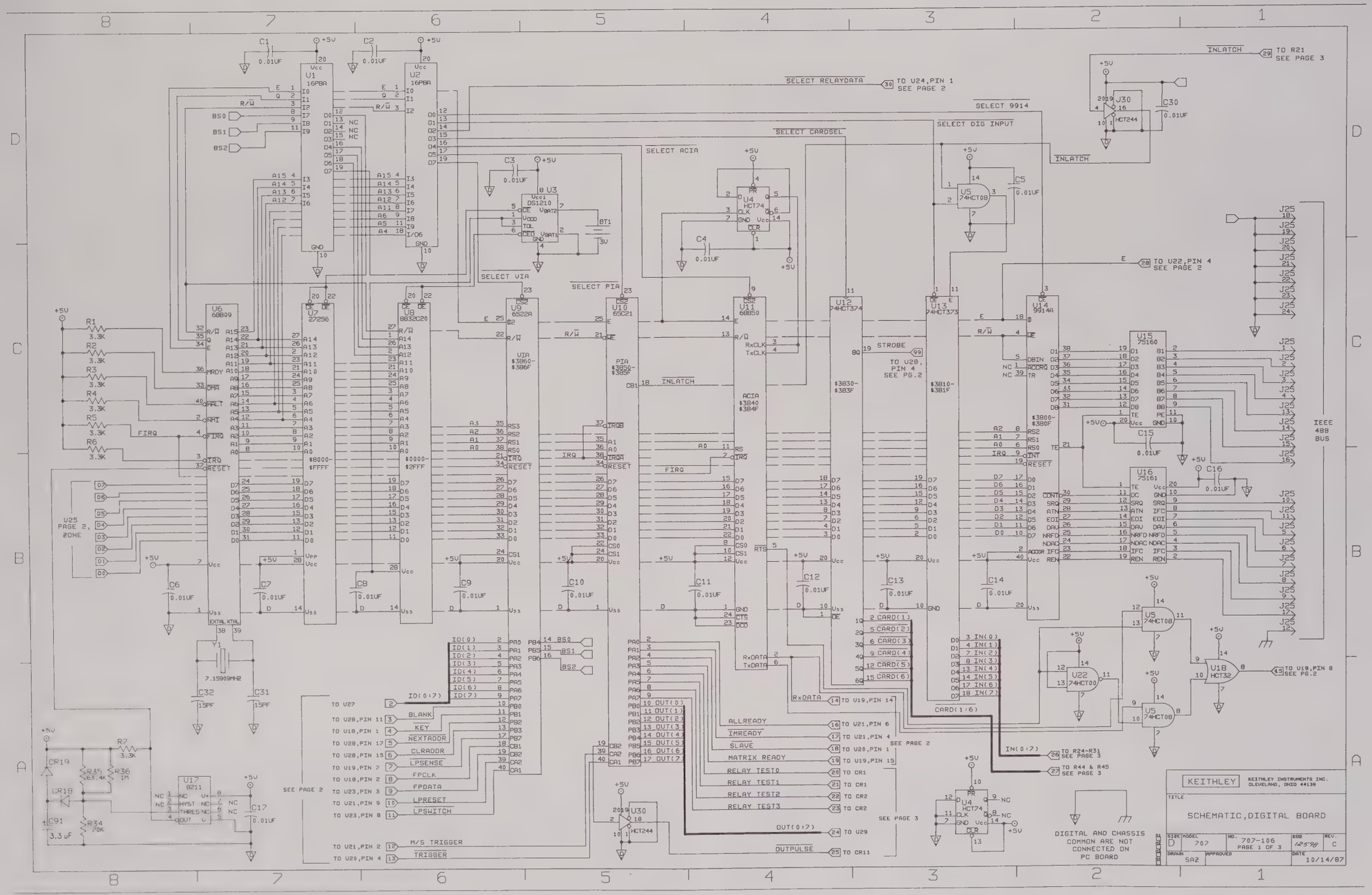
U17	IC,MICROPOWER BIPOLAR MONOLITHIC,6728	IC-177
U18	IC,QUAD 2 INPUT OR,74HCT32	IC-443
U19,U28..U30	IC,BUF/LINE DRIVER 74HCT244	IC-483
U2	IC,OCTAL 10 INPUT GATE ARRAY,PAL16P8A	IC-574
U20	IC,QUAD 2-INPUT MULTIPLEXER 74HCT157	IC-553
U21	IC,QUAD 2 INPUT POSITIVE NAND 7438	IC-154
U22	IC,QUAD 2 INPUT NAND,74HCT00	IC-399
U23	IC,BUF/LINE DRIVER 74HCT125	IC-552
U25,U26	IC,8 BIT PARALLEL TO SERIAL,74HCT165	IC-548
U27	IC,8 BIT PAR OUT SHIFT REG,74HCT164	IC-456
U3	IC,NONVOLATILE CONTROLLER DS1210	IC-541
U4,U24	IC,DUAL D FLIP FLOP, 74HCT74	IC-515
U5	IC,QUAD 2 INPUT AND GATE 74HCT08	IC-550
U6	8-BIT MICROPROCESSING UNIT,68B09	LSI-65
U7	PROGRAM	707-801-*
U8	IC,32Kx8 STATIC CMOS RAM D43256C-15L	LSI-76
U9	IC,VIA,6522A	LSI-45
Y1	CRYSTAL,7.15909MHZ	CR-24-4

*Order same software as presently installed. For example, if the software revison level is A01, then order 707-801-A01.

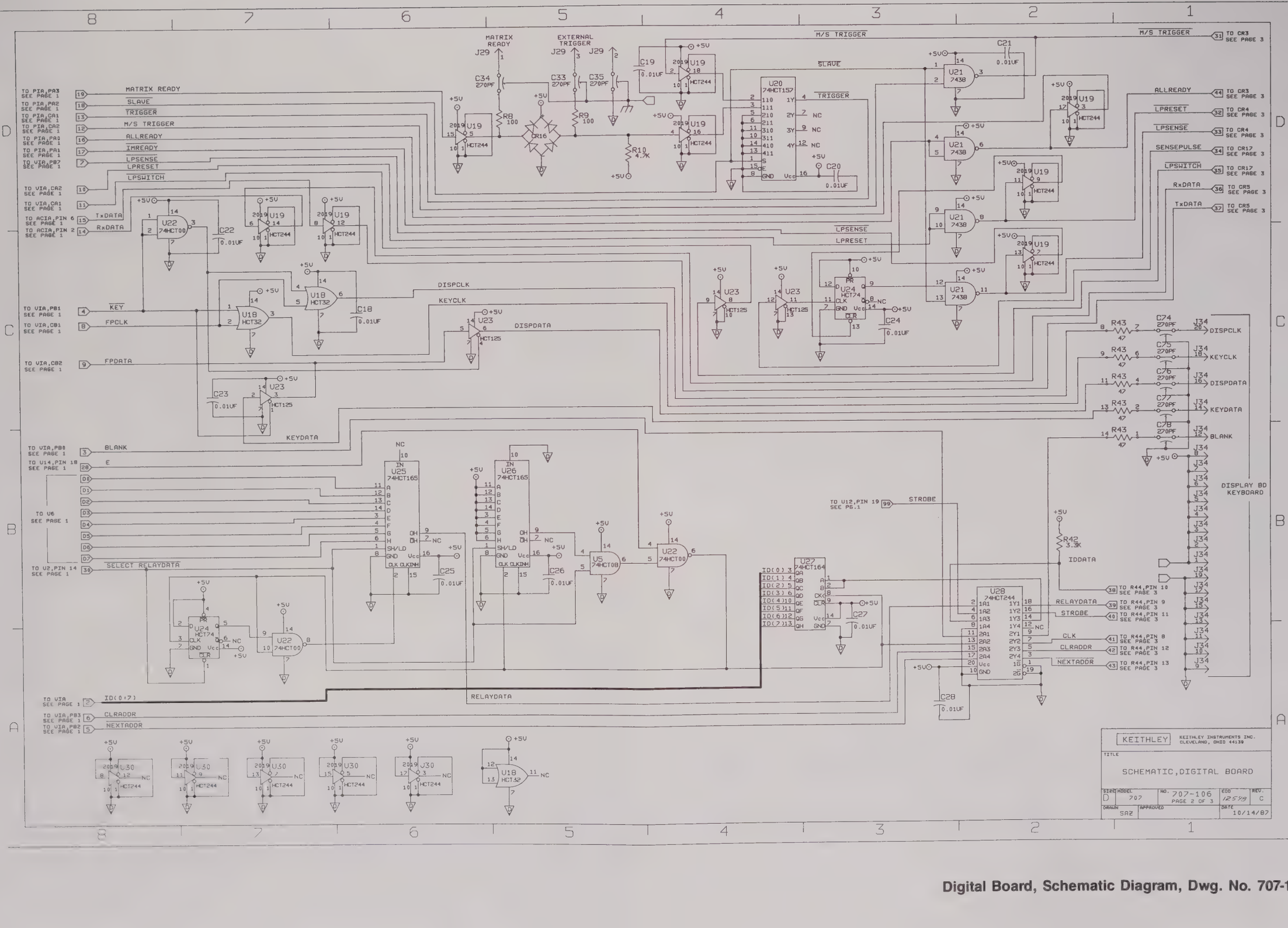
LTR.	ECO NO.	REVISION	ENG.	DATE
A	12185	RELEASED		6-12-87
B	12434	REVISED	SZ	10/15/87
C	12598	REVISED		1-28-88



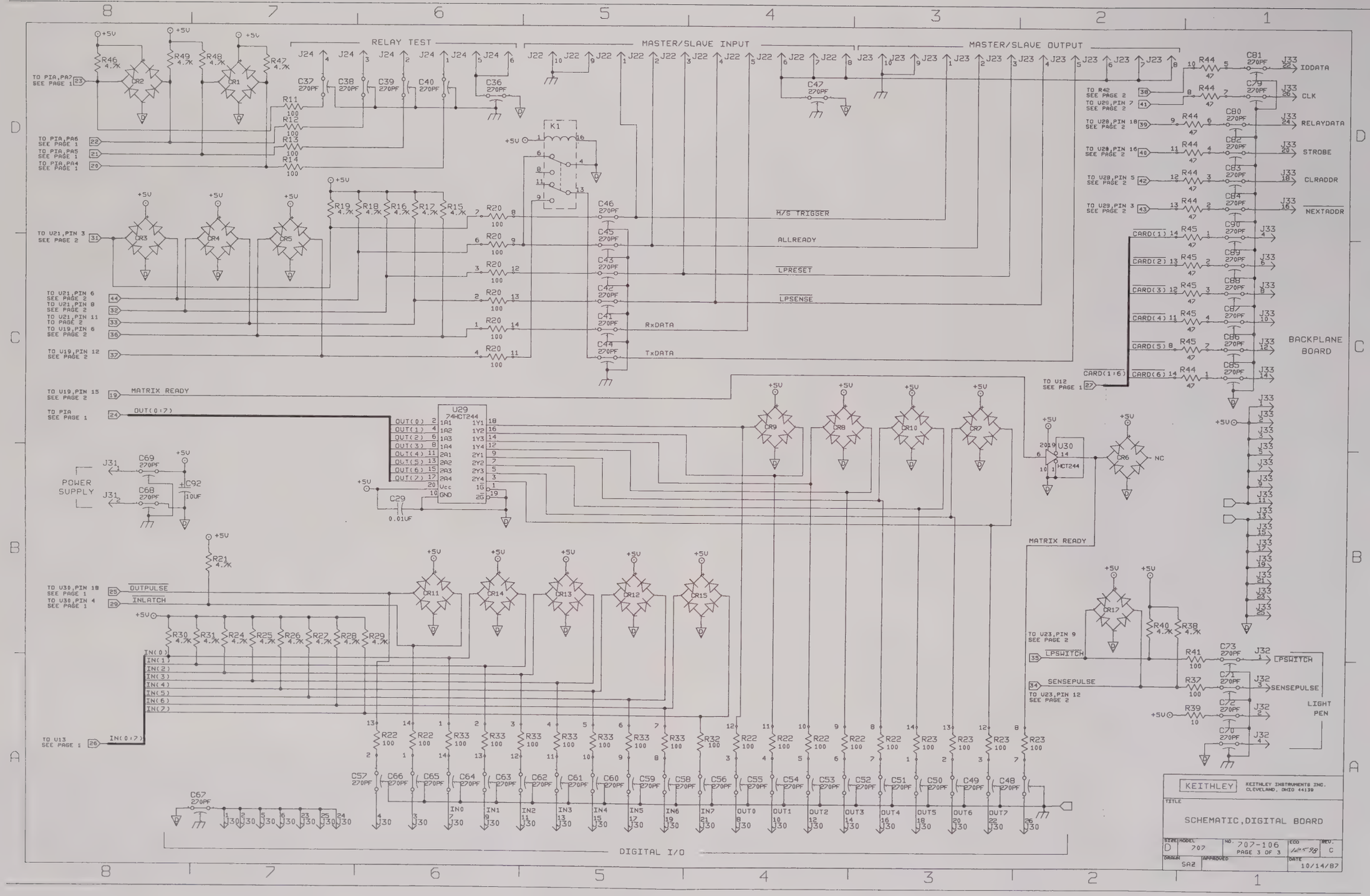
Digital Board, Component Location Drawing, Dwg. No. 707-100



Digital Board, Schematic Diagram, Dwg. No. 707-106 (sheet 1 of 3)



Digital Board, Schematic Diagram, Dwg. No. 707-106 (sheet 2 of 3)

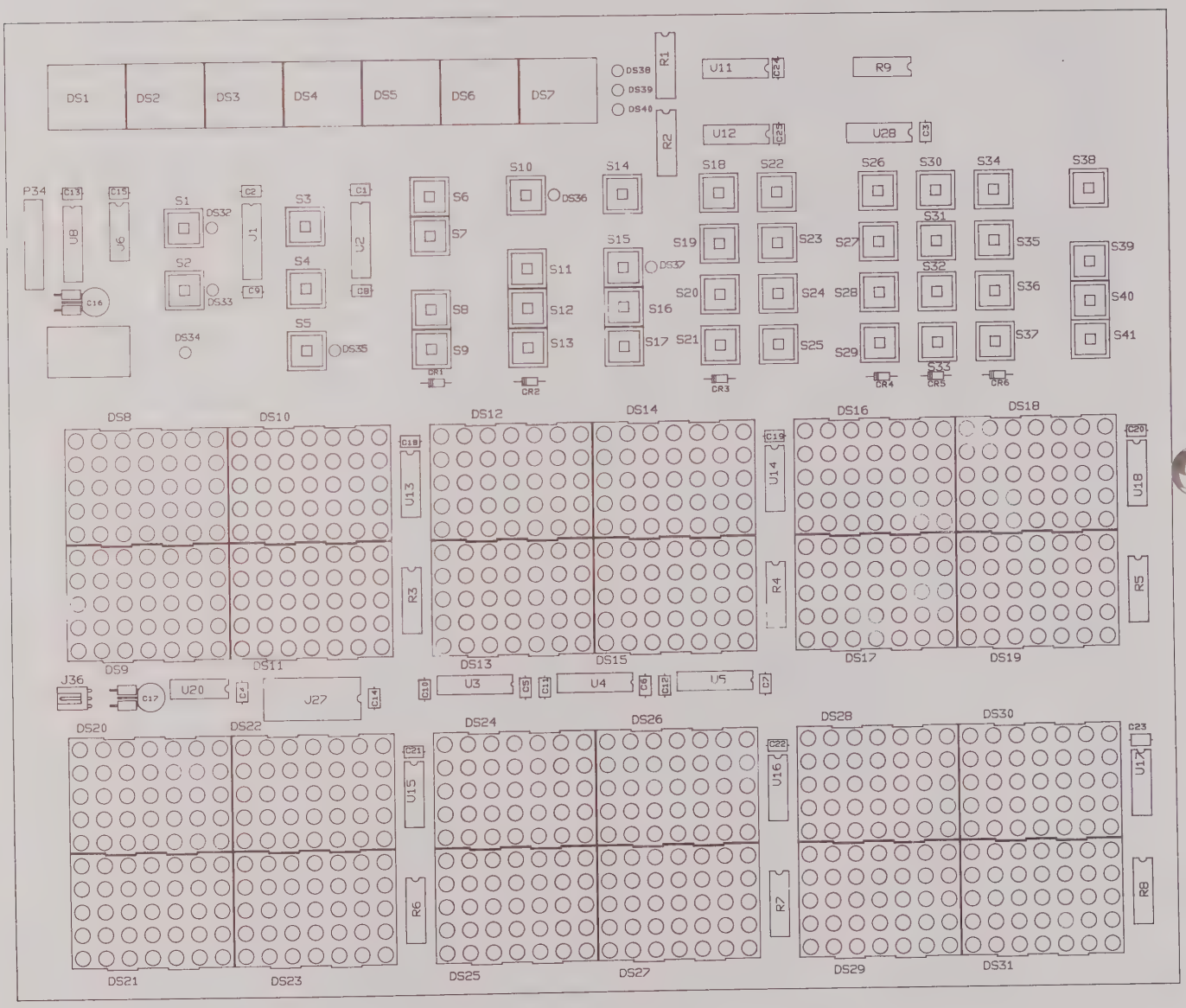


Digital Board, Schematic Diagram, Dwg. No. 707-106 (sheet 3 of 3)

MODEL 707 DISPLAY BOARD, PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART No.
C16,C17 C18..C25	CAP,270pF,20%,100V,CERAMIC/FERRITE	C-386-270P
C1..C7,C13..C15	CAP,.01uF,20%,50V,CERAMIC	C-365-.01
C8..C12	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
CR1..CR6	DIODE,SILICON,1N4148 (DO-35)	RF-28
DS1..DS7	DISPLAY,DIGITAL (DOUBLE DIGIT)	DD-39
DS32..DS34, DS36..DS40	PILOT LIGHT,RED,LED	PL-71
DS35	PILOT LIGHT,YEL,LED	PL-72
DS8..DS31	DIG DISP,(5x7 DOT MATRIX DISP),2057-AHR	DD-44
J36	CONN,MALE,3 PIN	CS-612-1
P34	CABLE ASSEMBLY,20 CONDUCTOR	CA-27-8
R1,R2	RES NET,82,5%,.25W	TF-141
R3..R8	RES NET,150,2%,.25W	TF-165-1
R9	RES NET,1M,5%,.11W	TF-102-2
S1..S41	SWITCH,MOMENTARY	SW-435
U11..U18	IC,8-BIT SERIAL-INPUT,5895A-2	IC-537
U1..U5	IC,8 CHANNEL DRIVER 2597A	IC-538
U20	IC,8 BIT PAR OUT SHIFT REG,74HCT164	IC-456
U27	IC,4-16 LINE DECODER/MULTI 74HCT154	IC-551
U28	IC,8 BIT PARALLEL TO SERIAL,74HCT165	IC-548
U6	IC,HEX INVERTER,74HCT04	IC-444
U8	IC,BUF/LINE DRIVER 74HCT244	C-483

LTR.	ECO NO.	REVISION	ENG.	DATE
A	12226	RELEASED	SZ	6-24-87
B	12424	REVISED		2-10-88



Display Board, Component Location Drawing, Dwg. No. 707-110

LEFT MOST

RIGHT MOST

DS1 DS2 DS3 DS4 DS5 DS6 DS7

R1 8 @ 82

R2 8 @ 82

U11 5895A-2

U12 5895A-2

+5V +6V

DISPDATA

DISPCLK

BLANK

DS32 DS33 DS34 DS35 DS36 DS37 DS38 DS39 DS4Ø

MEMORY RELAYS CROSSPOINT DISPLAY MODIFIED AUTO-MATIC MENU ENABLE TALK LISTEN REMOTE

C18-25 +5V Ø.Ø1UF

REPEAT=8

NOTE:
THESE BY-PASS CAPACITORS ARE FOR U11 THRU U18.

+6V +5V

C9 Ø.1UF C2 Ø.Ø1UF

U1 2597A

C8 Ø.1UF C1 Ø.Ø1UF

U2 2597A

Vk Vcc GND GND

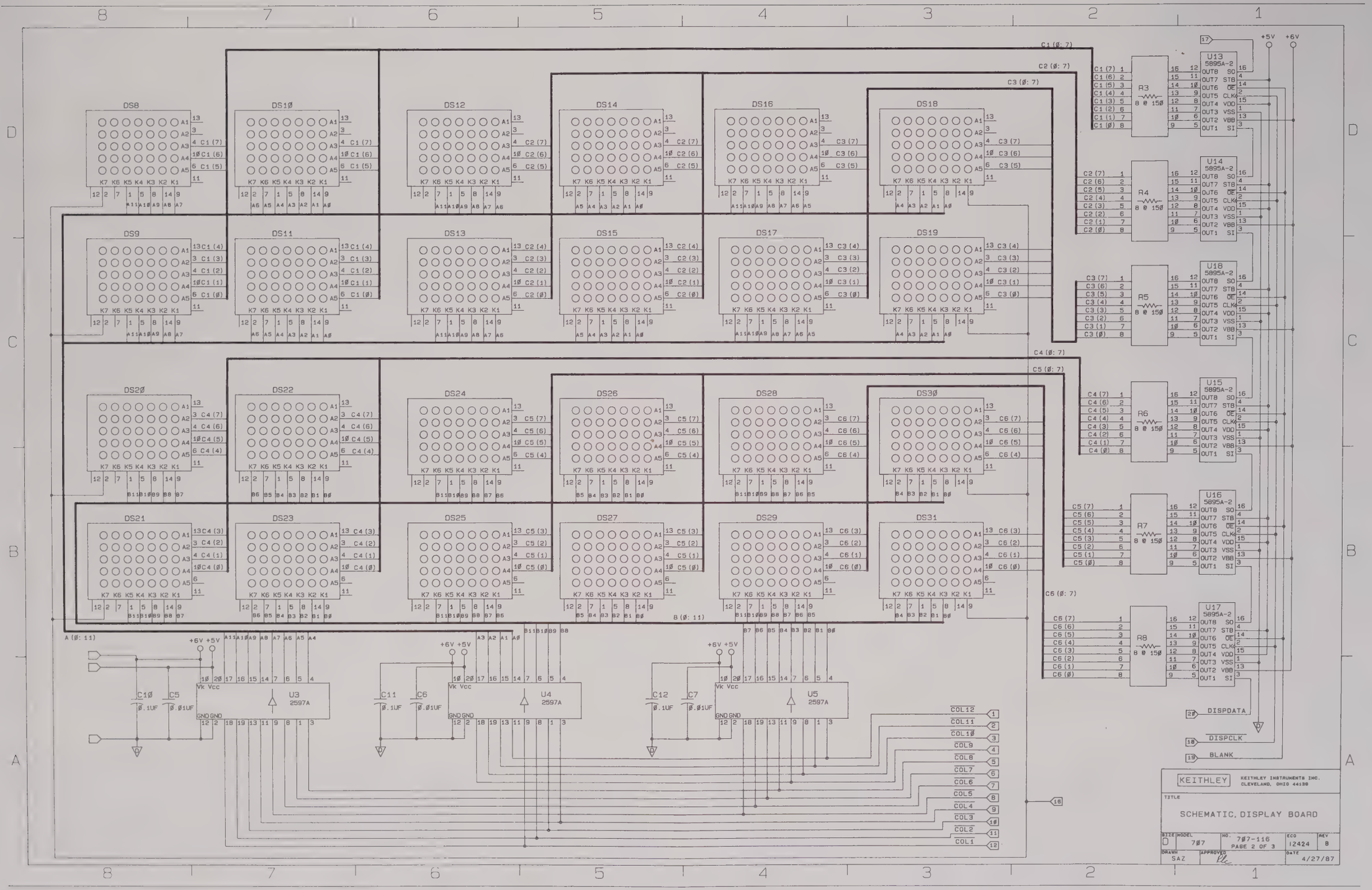
DIGIT14
DIGIT13
DIGIT12
DIGIT11
DIGIT1Ø
DIGIT9
DIGIT8
DIGIT7
DIGIT6
DIGIT5
DIGIT4
DIGIT3
DIGIT2
DIGIT1
ANNUNCIATORS

KEITHLEY KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44138

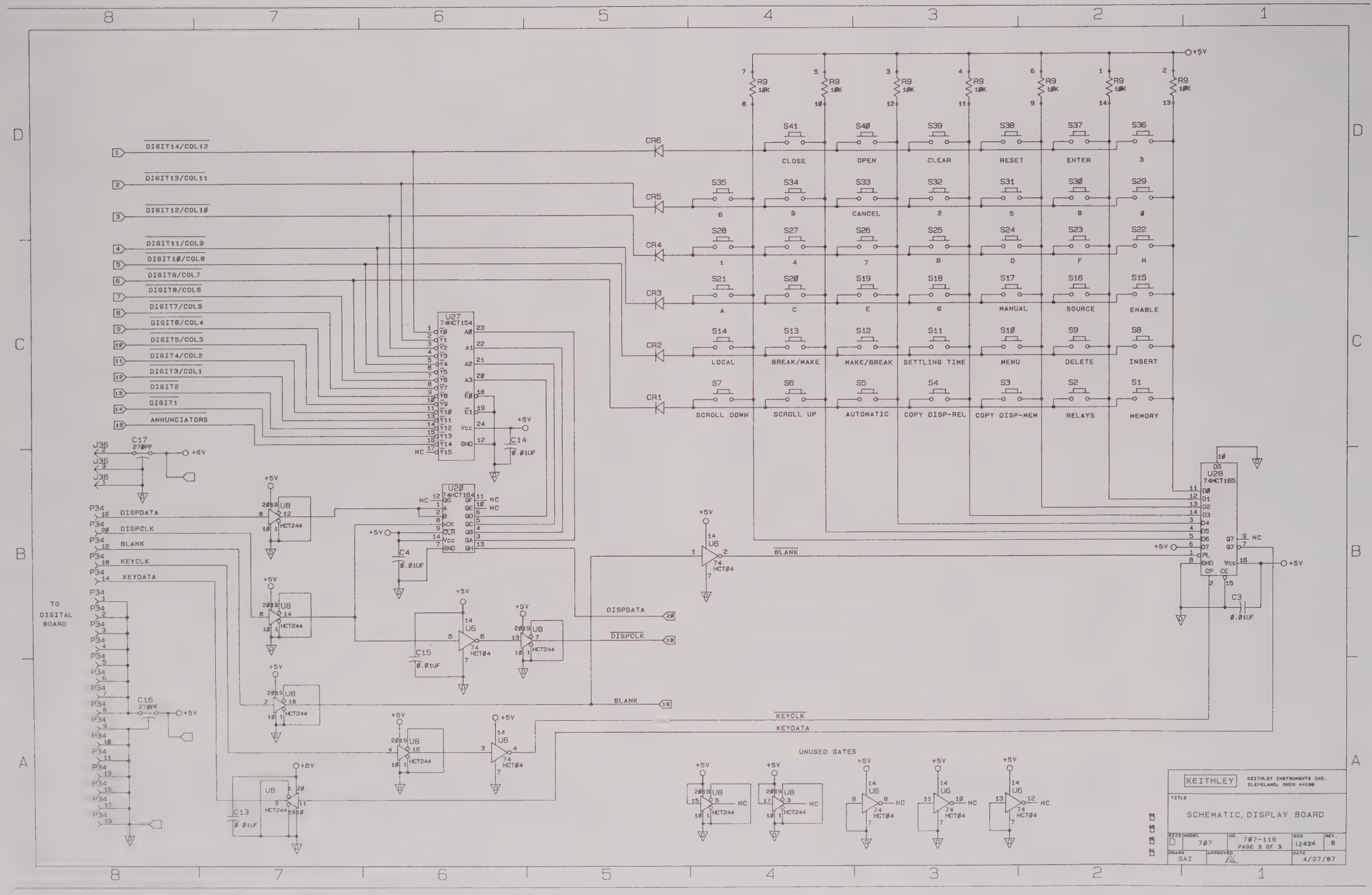
TITLE: SCHEMATIC, DISPLAY BOARD

SIZE	MODEL	NO.	ECO	REV
D	7Ø7	7Ø7-116 PAGE 1 OF 3	12424	B
DRAWN: SAZ	APPROVED:	DATE: 4/27/87		

Display Board, Schematic Diagram, Dwg. No. 707-116 (sheet 1 of 3)



Display Board, Schematic Diagram, Dwg. No. 707-116 (sheet 2 of 3)

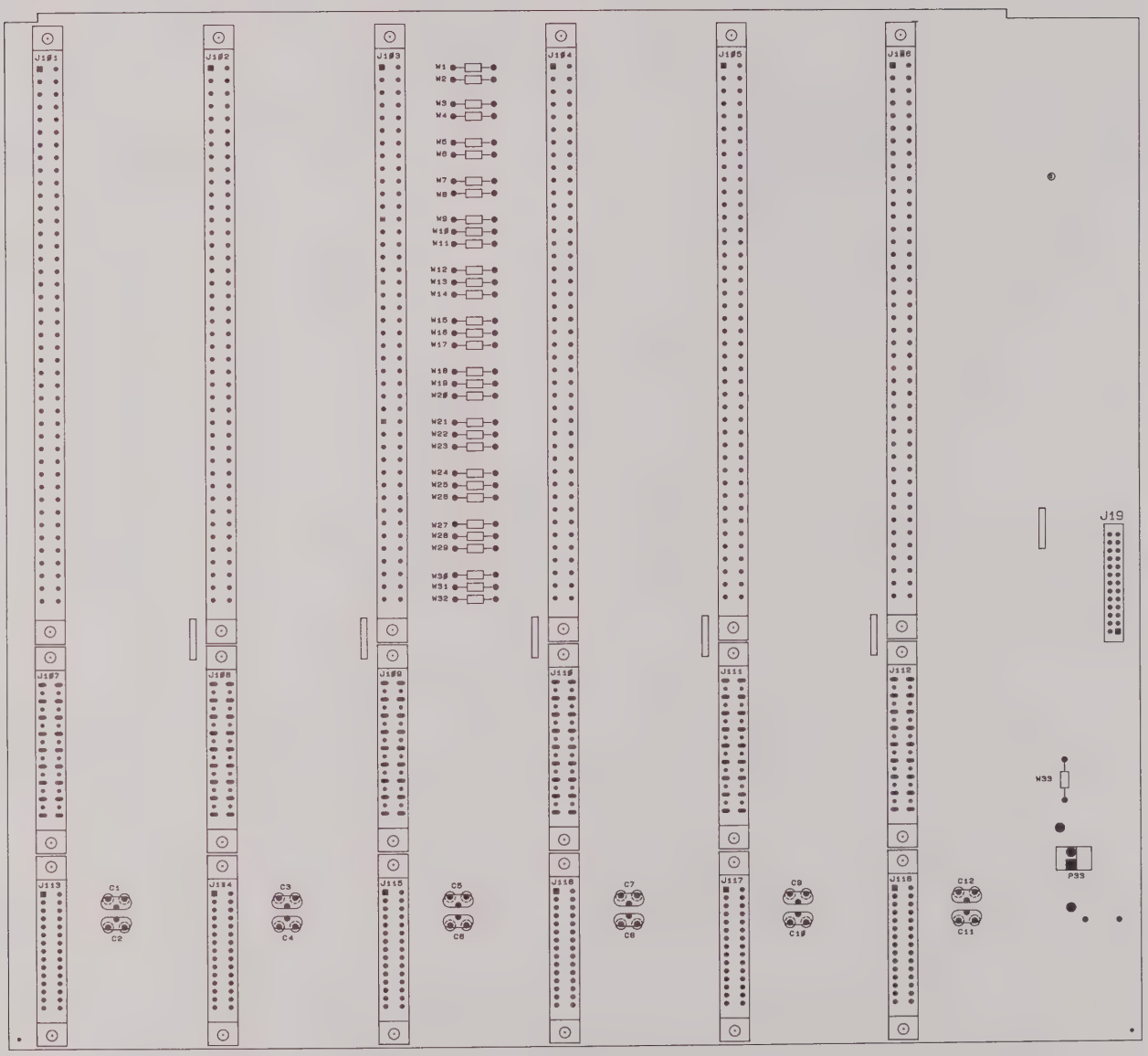


Display Board, Schematic Diagram, Dwg. No. 707-116 (sheet 3 of 3)

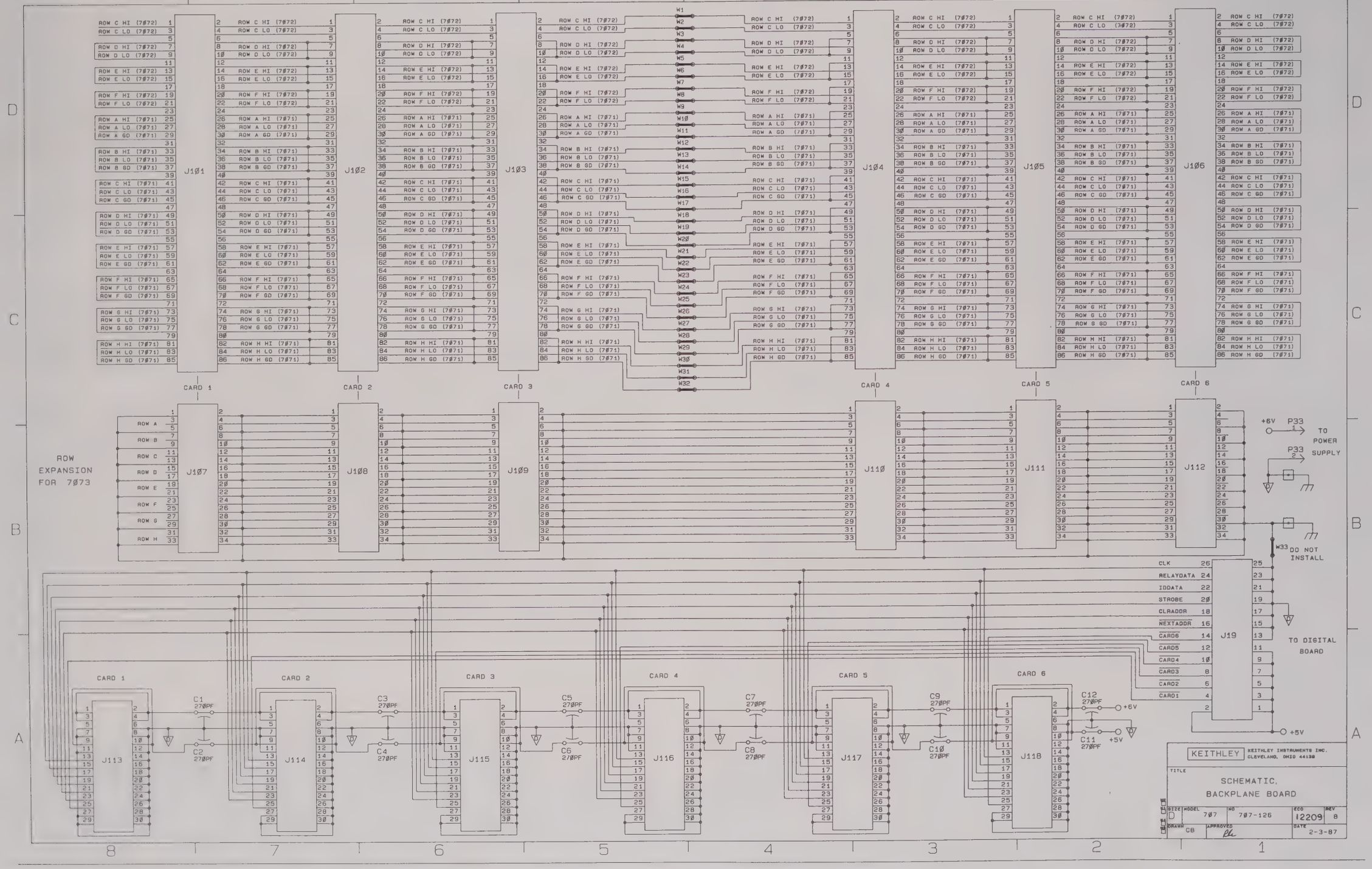
MODEL 707 BACKPLANE BOARD, PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART No.
C1..C12	CAP,270pF,20%,100V,CERAMIC/FERRITE	C-386-270P
J101..J106	CONNECTOR	CS-579-1
J107..J112	CONNECTOR	CS-591-2
J113..J118	CONNECTOR	CS-591-1
J119	CONNECTOR	CS-288-2
P33	CABLE ASSEMBLY	CA-27-7
W1...W33	JUMPER	J-15

LTR.	ECO NO.	REVISION	ENG.	DATE
B	12289	RELEASED		6-16-87



Backplane Board, Component Location Drawing, Dwg. No. 707-120

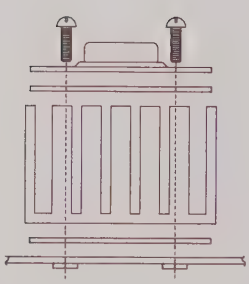


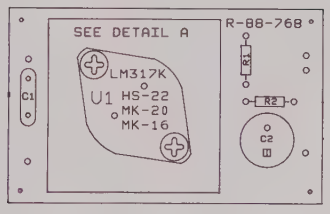
Backplane Board, Schematic Diagram, Dwg. No. 707-126

MODEL 707 VOLTAGE REGULATOR BOARD, PARTS LIST

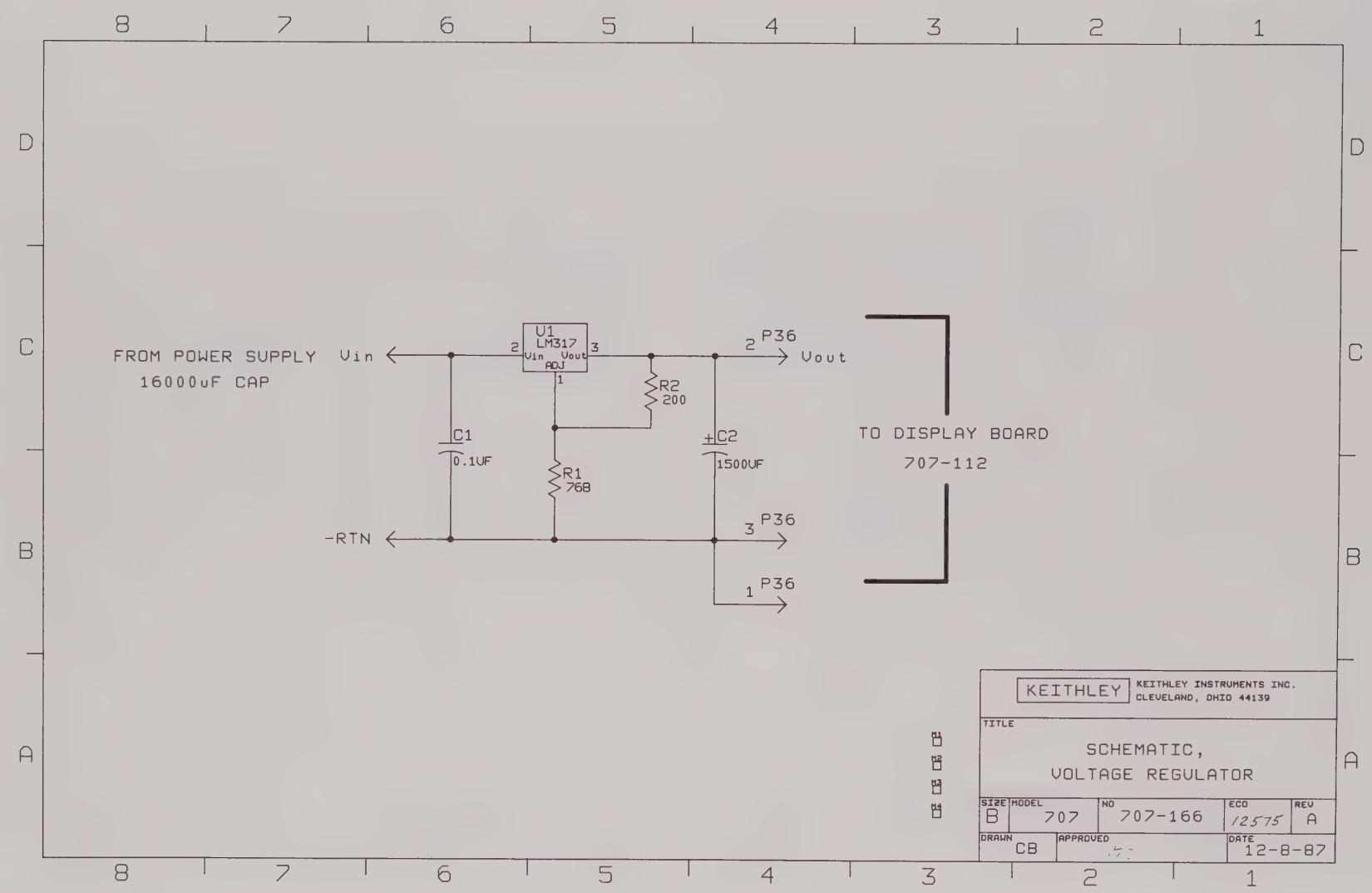
CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART No.
C1	CAP,0.1uF,+80-20%,16V,CERAMIC	C-238-.1
C2	CAP,1500uF,-20+100%,25V,ALUM ELECT	C-314-1500
R1	RES,768,1%,1/8W,METAL FILM	R-88-768
R2	RES,200,1%,1/8W,METAL FILM	R-88-200
U1	IC,REG. 3 TERM'L ADJUSTABLE,LM317K	IC-599

LTR.	ECO NO.	REVISION	ENG.	DATE
A	12575	RELEASED		





Voltage Regulator, Component Location Drawing, Dwg. No. 707-160



Voltage Regulator, Schematic Diagram, Drawing No. 707-166

MODEL 707 MISCELLANEOUS, PARTS LIST

QUANTITY	DESCRIPTION	KEITHLEY PART No.
1	CHASSIS ASSEMBLY	707-301
1	FRONT PANEL	707-310
1	REAR PANEL	707-311
1	SHIELD, DISPLAY BOARD	707-313
	FRONT PANEL	
2	HANDLE	HH-30-4
1	OVERLAY	707-308
1	BRACKET, RACK MOUNT, LEFT	707-317
1	BRACKET, RACK MOUNT, RIGHT	707-319
1	WINDOW (ALPHANUMERIC DISPLAY)	194-303
1	SWITCH (POWER)	SW-420
1	PUSHBUTTON, RED	29465-3
1	CONNECTOR (LIGHT PEN)	CS-458
3	STANDOFF, DISPLAY SHIELD	707-307
2	STANDOFF	ST-155-1
	REAR PANEL	
1	FAN	FN-8
1	FILTER	FL-6
1	BINDING POST (CHASSIS GROUND)	BP-15
2	CONNECTOR, BNC	CS-15
1	LINE FILTER	LF-2
1	FUSE HOLDER BODY	FH-24
1	FUSE CARRIER	FH-25
1	FUSE, 2A (115V)	FU-25
1	FUSE, 1A, (230V)	FU-10
1	IEEE HARDWARE KIT (FOR IEEE CONNECTOR)	CS-378
1	LINE CORD	CO-7
1	SWITCH, SLIDE	SW-471
1	DIGITAL I/O RIBBON CABLE ASSEMBLY	CA-60-1
5	BLANK PANEL (SLOT COVER)	707-316
	DIGITAL BOARD	
1	BATTERY HOLDER	BH-34
2	SOCKET (FOR U1, U2)	SO-84-20
1	SOCKET (FOR U7)	SO-69
3	SOCKET (FOR U6, U9, U10)	SO-84-40
	DISPLAY BOARD	
8	NYLON LED MOUNTS (FOR PL-71)	MK-22-1
1	NYLON LED MOUNTS (FOR PL-72)	MK-22-2
5	PUSHBUTTON (CROSSPOINT DISPLAY GROUP)	228-317-4
12	PUSHBUTTON (SCROLL, MEMORY, MENU, SWITCHING, LOCAL, TRIGGER)	228-317-5

20	PUSHBUTTON (DATA ENTRY)	228-317-6
4	PUSHBUTTON (RESET, CLEAR, OPEN, CLOSE)	228-317-7
	VOLTAGE REGULATOR BOARD	
1	MOUNTING KIT, TO-3	MK-16
1	MOUNTING KIT	MK-20
1	HEATSINK	HS-22
1	BRACKET	707-323
4	STANDOFF, 4-40	ST-137-7
	FIXED RACK MOUNTING KIT	
1	CHASSIS SUPPORT, LEFT	707-321
1	CHASSIS SUPPORT, RIGHT	707-322
1	BRACKET KIT	BR-31
4	CAPTIVE NUT	FA-148
1	POWER SUPPLY, 6V	PS-24
1	POWER SUPPLY, 5V	PS-4
1	TERMINAL BLOCK	TE-106-4
1	TERMINAL BLOCK COVER	TE-107-4
1	RELAY TEST SOFTWARE (5-1/4" DISK)	707-851
1	RELAY TEST SOFTWARE (3-1/2" DISK)	707-852
1	3-RING BINDER, 2"	590-341
1	3-RING BINDER, 1-1/2"	590-340
1	3-RING BINDER, 1"	500-320
1	BINDER COVER AND SPINE (FOR 2" BINDER)	MC-491

MODEL 707 MISCELLANEOUS, PARTS LIST

QUANTITY	DESCRIPTION	KEITHLEY PART No.
1	CHASSIS ASSEMBLY	707-301
1	FRONT PANEL	707-310
1	REAR PANEL	707-311
1	SHIELD, DISPLAY BOARD	707-313
	FRONT PANEL	
2	HANDLE	HH-30-4
1	OVERLAY	707-308
1	BRACKET, RACK MOUNT, LEFT	707-317
1	BRACKET, RACK MOUNT, RIGHT	707-319
1	WINDOW (ALPHANUMERIC DISPLAY)	194-303
1	SWITCH (POWER)	SW-420
1	PUSHBUTTON, RED	29465-3
1	CONNECTOR (LIGHT PEN)	CS-458
3	STANDOFF, DISPLAY SHIELD	707-307
2	STANDOFF	ST-155-1
	REAR PANEL	
1	FAN	FN-8
1	FILTER	FL-6
1	BINDING POST (CHASSIS GROUND)	BP-15
2	CONNECTOR, BNC	CS-15
1	LINE FILTER	LF-2
1	FUSE HOLDER BODY	FH-24
1	FUSE CARRIER	FH-25
1	FUSE, 2A (115V)	FU-25
1	FUSE, 1A, (230V)	FU-10
1	IEEE HARDWARE KIT (FOR IEEE CONNECTOR)	CS-378
1	LINE CORD	CO-7
1	SWITCH, SLIDE	SW-471
1	DIGITAL I/O RIBBON CABLE ASSEMBLY	CA-60-1
5	BLANK PANEL (SLOT COVER)	707-316
	DIGITAL BOARD	
1	BATTERY HOLDER	BH-32
2	SOCKET (FOR U1, U2)	SO-84-20
1	SOCKET (FOR U7)	SO-69
3	SOCKET (FOR U6, U9, U10)	SO-84-40
	DISPLAY BOARD	
8	NYLON LED MOUNTS (FOR PL-71)	MK-22-1
1	NYLON LED MOUNTS (FOR PL-72)	MK-22-2
5	PUSHBUTTON (CROSSPOINT DISPLAY GROUP)	228-317-4
12	PUSHBUTTON (SCROLL, MEMORY, MENU, SWITCHING, LOCAL, TRIGGER)	228-317-5

20	PUSHBUTTON (DATA ENTRY)	228-317-6
4	PUSHBUTTON (RESET, CLEAR, OPEN, CLOSE)	228-317-7
	VOLTAGE REGULATOR BOARD	
1	MOUNTING KIT, TO-3	MK-16
1	MOUNTING KIT	MK-20
1	HEATSINK	HS-22
1	BRACKET	707-323
4	STANDOFF, 4-40	ST-137-7
	FIXED RACK MOUNTING KIT	
1	CHASSIS SUPPORT, LEFT	707-321
1	CHASSIS SUPPORT, RIGHT	707-322
1	BRACKET KIT	BR-31
4	CAPTIVE NUT	FA-148
1	POWER SUPPLY, 6V	PS-24
1	POWER SUPPLY, 5V	PS-4
1	TERMINAL BLOCK	TE-106-4
1	TERMINAL BLOCK COVER	TE-107-4
1	RELAY TEST SOFTWARE (5-1/4" DISK)	707-851
1	RELAY TEST SOFTWARE (3-1/2" DISK)	707-852

APPENDIX A

Card Configuration Worksheet

Model 707 Card Configuration

Slot _____		Model _____	
Mainframe:	Stand-alone ____	Master _____	
	Slave1 _____	Slave2 _____	Slave3 _____ Slave4 _____
System Size: ____	rows _____	columns _____	IEEE Address _____

FROM (Instrument connection or DUT pin)	External Card Connection	TO (Instrument connection or DUT pin)
	Row A	
	B	
	C	
	D	
	E	
	F	
	G	
	H	
	Column 1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	11	
	12	

Expansion:

—Backplane bus (rows) —SMB coax jumpers (rows)

—Point to point wiring (rows/cols.) —Mass terminated cable (rows/cols.)

—BNC coax cable (rows/columns) —Triax cable (rows/cols.)

Notes:

APPENDIX B

Controller Programs

The following programs have been supplied as a simple aid to the user and are not intended to suit specific needs. Each program allows you to send a device-dependent command string to the instrument and obtain and display a string from the instrument.

Programs for the following controllers are included:

- A BASIC program for an IBM PC/XT/AT with a Capital Equipment Corporation PC< >488 Interface (Keithley Model PC-488-CEC IEEE-488 Interface Card).
- A program written with the ASYST software package (available from Keithley Instruments) for an IBM PC/XT/AT with a Capital Equipment Corporation PC< >488 Interface
- A BASIC program for a Hewlett-Packard Model 9000 Series 200/300 computer.

IBM PC/XT/AT with Capital Equipment Corporation PC< >488 Interface (Keithley PC-488-CEC)

INTRODUCTION

General information about controlling a Model 707 with an IBM PC/XT/AT computer and Capital Equipment Corporation PC< >488 interface is given here. Refer to the CEC PC< >488 Programming and Reference Manual for complete information.

INITIALIZING THE SYSTEM

The first step in any program is to initialize the system using the INITIALIZE routine. This routine sets the primary IEEE-488 bus address of the PC< >488, specifies the type of controller to be used, and sends an interface clear (IFC) to the other devices on the bus.

After booting up the IBM using DOS and entering BASICA, the following statements can be used at the start of any program to initialize the system:

PROGRAM	COMMENTS
`10 DEF SEG=&HC400`	' Memory offset.
`20 INITIALIZE=0`	' Offset address of routine.
`30 MY.ADDRESS%=21`	' Set PC< >488 address.
`40 CONTROLLER%=0`	' Set for system control.
`50 CALL INITIALIZE(MY.ADDRESS%, CONTROLLER%)`	' Execute INITIALIZE routine.

Line 30 sets the address of the PC< >488 to 21, however, any other valid address could be used as long as it does not conflict with the address of any other device on the bus.

INTERFACE BASIC PROGRAMMING STATEMENTS

This paragraph covers the PC< >488 statements that are essential to Model 707 operation. A partial list of programming statements is contained in Table B-1. The IBM BASIC CALL statement is used to execute the desired action. Before a CALL routine can be used, BASIC needs to know the offset address of the routine. In the table, the first statement of each programming sequence defines the offset address of the CALL routine.

EXAMPLE PROGRAM

The following program sends a command string from an IBM PC/XT/AT computer to the Model 707 and displays the response on the CRT. The computer must be equipped with a CEC interface card and DOS 2.0 (or later revision) operating system.

DIRECTIONS

1. Using the front panel menu feature, set the primary IEEE-488 address of the Model 707 to 18.
2. With the power off, connect the Model 707 to the IEEE-488 interface card installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into the IBM interpretive BASIC language.
4. Enter the lines below using the return key after each line.
5. Run the program and type in the desired command string at the ENTER COMMAND STRING? prompt. For example, to close crosspoint A1, type in CA1X and press the return key. (The Model 707 software revision, e.g. 707A01, will then appear on the computer display for device-dependent commands which have no response.)

   If the command "G2U2,0X" is typed in at the prompt, the response will be a display of the closed crosspoints of the current relay setup.

PROGRAM	COMMENTS
`10 DEF SEG=&HC400`	' Memory address
`20 INITIALIZE=0`	' Offset address of routine
`30 SEND=9:ENTER=21`	' Routine addresses
`40 MY.ADDRESS%=21`	' Set PC< >488 address
`50 INST.ADDRESS%=18`	' Set 707 address
`60 CONTROLLER%=0`	' Set for system control
`70 CALL INITIALIZE (MY.ADDRESS%, CONTROLLER%)`	' Initialize system
`80 LINE INPUT ''ENTER COMMAND STRING: '';CMD$`	' Prompt for string
`90 CALL SEND (INST.ADDRESS%,CMD$, STATUS%)`	' Send command string
`100 RESPONSE$=SPACE$(80)`	' Make room for data
`110 CALL ENTER (RESPONSE$,LENGTH%, INST.ADDRESS%,STATUS%)`	' Get response from 707
`120 PRINT RESPONSE$`	' Display response
`130 GOTO 80`	' Repeat
`140 END`	

Table B-1. BASIC Statements Necessary to Send Bus Commands

Action	PC< >488 Statements
Transmit command string (CMD$) to device 18.	SEND=9 ADDRESS%=18 CALL SEND(ADDRESS%,CMD$,STATUS%)
Obtain string from device 18.	ENTER=21 ADDRESS%=18: RESPONSE$=SPACE$(50) CALL ENTER(RESPONSE$,LENGTH%, ADDRESS%,STATUS%)
Send GTL to device 18.	TRANSMIT=3 CMD$=''LISTEN 18 GTL'' CALL TRANSMIT(CMD$,STATUS%)
Send SDC to device 18.	TRANSMIT=3 CMD$=''LISTEN 18 SDC'' CALL TRANSMIT(CMD$,STATUS%)
Send DCL to all devices.	TRANSMIT=3 CMD$=''LISTEN 18 DCL'' CALL TRANSMIT(CMD$,STATUS%)
Send remote enable.	TRANSMIT=3 CMD$=''REN LISTEN 18'' CALL TRANSMIT(CMD$,STATUS%)
Serial poll device 18.	SPOLL=12 ADDRESS%=18 CALL SPOLL%(ADDRESS%,POLL%, STATUS%)

IBM PC/XT/AT with CEC PC< >488 Interface and ASYST Software Package

INTRODUCTION

ASYST contains data acquisition, analysis, and graphing software in four integrated modules. It has two modes of operation: interactive execution of commands and programmable execution.

The ASYST program listed here sends a command string from an IBM PC/XT/AT computer to the Model 707 and displays the response on the CRT. The computer must be equipped with a CEC interface card and DOS 2.0 (or later revision) operating system.

The optional GPIB/IEEE-488 software module for the ASYST package is required. Hardware requirements for ASYST include: 640K RAM, math coprocessor, parallel port, and hard drive (recommended).

DIRECTIONS

This procedure will help an ASYST user through the steps necessary for GPIB configuration, program entry, and program execution. Refer to the ASYST documentation for more detailed instructions.

1. Using the front panel menu key, set the primary IEEE-488 address of the Model 707 to 18.
2. With the power off, connect the Model 707 to the IEEE-488 interface card installed in the IBM computer.
3. Boot ASYST software from DOS. You will get an OK prompt.
4. Use the <F2> key to enter the Main Configuration Menu. In addition to the usual configuration requirements of ASYST, the GPIB must be configured.

   From the Overlay Configuration Menu, select overlays GPIB Master and Type 1 NEC GPIB Driver.

   From the GPIB Configuration Menu, select a bus number, board type (National GPIB-PC1 or GPIB-PC2), memory address (2B8), primary address (0), and interrupt line.
5. Save your changes and return to the OK prompt.
6. Use the command line editor (EDIT 707.DMO) to enter the following program. Save the program and exit the editor.
7. When prompted, load the program with the L key, or type LOAD 707.DMO from the OK prompt.
8. When the program loads properly, type MAIN from the OK prompt to start execution.
9. Type in the desired command string at the "Enter command string:" prompt. For example, to close crosspoint A1, type in CA1X and press the return key. (The Model 707 software revision, e.g. 707A01, will then appear on the computer display for device-dependent commands which have no response.)

   If the command "G2U2,0X" is typed in at the prompt, the response will be a display of the closed crosspoints of the current relay setup.
10. Type <Control-Break> to exit the program loop of 707.DMO and return to the OK prompt. The program-defined words can be removed from the ASYST dictionary by typing FORGET 707.

PROGRAM	COMMENTS
BUS.INIT	\ Initialize bus
SEND.INTERFACE.CLEAR	\ Take control of bus
REMOTE.ENABLE.ON	\ Allow remote operation
SYNCHRONOUS.GPIB	\ Make sure ASYST is in sync. mode
?GPIB.DEVICES	\ List controller parameters
18 GPIB.DEVICE 707	\ Set 707 address and name
EOI.ON	\ Enable end or identify
EOS.ON	\ Enable end of string terminator
10 EOS.CHARACTER	\ Use LF terminator
1000 TIMEOUT	\ Set timeout of 1sec
?GPIB.DEVICE	\ List 707 parameters
100 STRING COMMAND	\ Allocate 100 bytes for user input
100 STRING RESPONSE	\ Allocate 100 bytes for 707 response
: GET.INPUT	\ Definition for user input
CR ." ENTER COMMAND STRING: "	\ Prompt user
"INPUT COMMAND ":=	\ Get DDCs
;	
: MAIN	\ Definition for main program
BEGIN	\ Start loop
ME	\ Make controller current device
GET.INPUT	\ Get DDCs from user
707	\ Make 707 current device
COMMAND GPIB.WRITE	\ Send DDCs to 707
RESPONSE GPIB.READ	\ Get response
CR RESPONSE "TYPE	\ Display response
AGAIN	\ Return for more commands
;	

Hewlett-Packard Model 9000 Series 200/300

INTRODUCTION

The following program sends a command string to the Model 707 from a Hewlett-Packard Model 9000 Series 200/300 computer and displays the response on the computer CRT. The computer must be equipped with HP BASIC 4.0.

DIRECTIONS

1. Using the front panel menu feature, set the primary IEEE-488 address of the Model 707 to 18.
2. With the power off, connect the Model 707 to the IEEE-488 interface card installed in the HP computer.
3. Enter the lines in the program below, using the ENTER/RETURN key after each line.
4. Press the RUN key and type in the desired command string at the COMMAND STRING prompt. For example, to close crosspoint A1, type in CA1X and press the ENTER/RETURN key. (The Model 707 software revision, e.g. 707A01, will then appear on the computer display for device-dependent commands which have no response.)

   If the command "G2U2,0X" is typed in at the prompt, the response will be a display of the closed crosspoints of the current relay setup.

PROGRAM	COMMENTS
`10 DIM A$[50],B$[50]`	
`20 REMOTE 718`	! Place 707 in remote.
`30 LINPUT ''COMMAND STRING: '',A$`	! Prompt for and input command.
`40 OUTPUT 718;A$`	! Address 707 to listen, send string.
`50 ENTER 718;B$`	! Address 707 to talk, input response.
`60 PRINT B$`	! Display response string.
`70 GOTO 30`	! Repeat.
`80 END`	

APPENDIX C

IEEE-488 Bus Overview

INTRODUCTION

Basically, the IEEE-488 bus is simply a communication system between two or more electronic devices. A device can be either an instrument or a computer. When a computer is used on the bus, it serves to supervise the communication exchange between all the devices and is known as the controller. Supervision by the controller consists of determining which device will talk and which devices will listen. As a talker, a device will output information and as a listener, a device will receive information. To simplify the task of keeping track of the devices, a unique address number is assigned to each one.

On the bus, only one device can talk at a time and is addressed to talk by the controller. The device that is talking is known as the active talker. All devices are instructed to unlisten by the controller, then the devices that need to listen to the talker are addressed to listen. Each listener is referred to as an active listener. The reasons for the unlisten instruction are so previous listeners do not try to execute unrelated device-dependent commands and to optimize the speed of bus information transfer since the task of listening takes up bus time.

Through the use of control lines, a handshake sequence takes place in the transfer process of information from a talker to a listener. This handshake sequence helps ensure the credibility of the information transfer. The basic handshake sequence between an active controller (talker) and a listener is as follows:

1. The listener indicates that it is ready to listen.
2. The talker places the byte of data on the bus and indicates that the data is available to the listener.
3. The listener, aware that the data is available, accepts the data and then indicates that the data has been accepted.
4. The talker, aware that the data has been accepted, stops sending data and indicates that data is not being sent.
5. The listener, aware that there is no data on the bus, indicates that it is ready for the next byte of data.

BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for both data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines.

A typical set up for controlled operation is shown in Figure C-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker and listener. The controller does what its name implies; it controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only or both a talker and a listener.

There are two catagories of controllers: system controller, and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary ad-

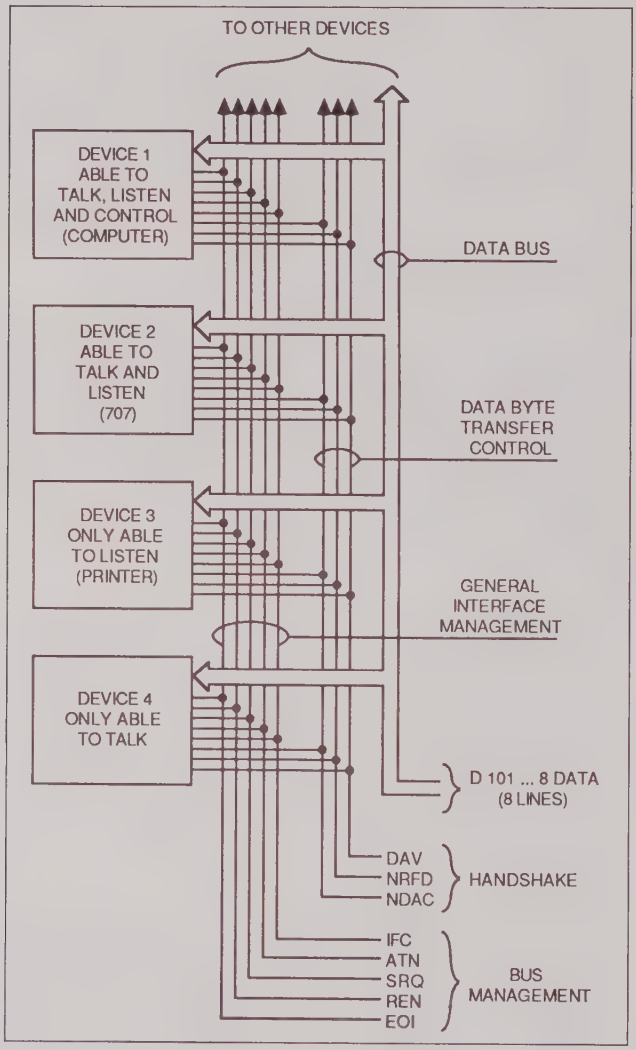


Figure C-1. IEEE Bus Configuration

dress. The primary address may have any value between 0 and 30, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For example, if the primary address is 18 decimal ($12), the actual listen address is $32 ($32 = $12 + $20). In a similar manner, the talk address is obtained by ORing the primary address with $40. With the present example, the talk address derived from a primary address of 18 decimal would be $52 ($52 = $12 + $40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of $60-$7F. Note, however that many devices, including the Model 707, do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example: if the instrument is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information and the appropriate software can be used to direct the information to the desired location.

BUS LINES

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation takes place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the operation of these lines.

Data Lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 (Data Input/Output) through DIO8 (Data Input/Output) are the eight data lines used to transmit both data and multiline commands and are bidirectional. The data lines operate with low true logic.

Bus Management Lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands.

ATN (Attention)—The ATN line is one of the more important management lines in that the state of this line determines how information on the data bus is to be interpreted.

IFC (Interface Clear)—As the name implies, the IFC line controls clearing of instruments from the bus.

REN (Remote Enable)—The REN line is used to place the instrument on the bus in the remote mode.

EOI (End or Identify)—The EOI line is usually used to mark the end of a multi-byte data transfer sequence.

SRQ (Service Request)—This line is used by devices when they require service from the controller.

Handshake Lines

The bus uses handshake lines that operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener or listeners receiving the information). The three handshake lines are:

DAV (Data Valid)—The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.

NRFD (Not Ready For Data)—The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

The complete handshake sequence for one data byte is shown in Figure C-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must by stable for at least 100nsec after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The sequence just described is used to transfer both data, talk and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses or commands as described in the following paragraph.

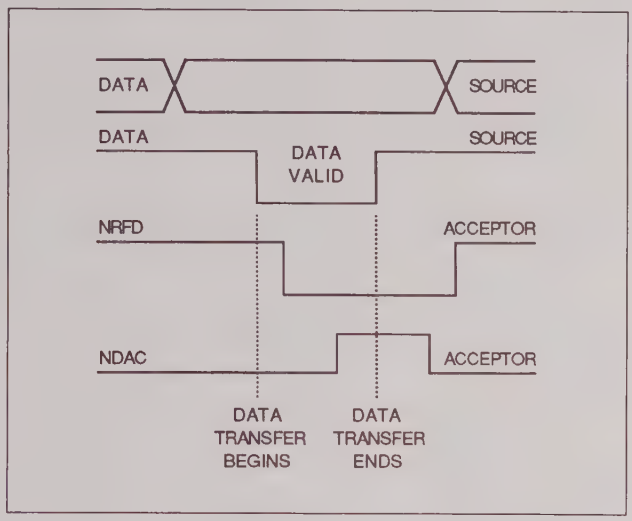


Figure C-2. IEEE-488 Handshake Sequence

BUS COMMANDS

The instrument may be given a number of special bus commands through the IEEE-488 interface. This section briefly describes the purpose of the bus commands which are grouped into the following three categories.

1. Uniline Commands - Sent by setting the associated bus lines true. For example, to assert REN (Remote Enable), the REN line would be set low (true).
2. Multiline Commands - General bus commands which are sent over the data lines with the ATN line true (low).
3. Device-Dependent Commands - Special commands whose meanings depend on device configurations; sent with ATN high (false).

These bus commands and their general purposes are summarized in Table C-1.

Uniline Commands

ATN, IFC and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

Table C-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Sets up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent		High	Programs Model 707 for various modes.

*X = Don't Care.

REN (Remote Enable)—REN is sent to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be sent before attempting to program instruments over the bus.

EOI (End Or Identify)—EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.

IFC (Interface Clear)—IFC is used to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention)—The controller sends ATN while transmitting addresses or multiline commands.

SRQ (Service Request)—SRQ is asserted by a device when it requires service from a controller.

Universal Multiline Commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the command is transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to the instrument to lock out front panel (local) operation of the instrument.

DCL (Device Clear)—DCL is used to return instruments to some default state. Usually, instruments return to their power-up conditions.

SPE (Serial Poll Enable)—SPE is the first step in the serial polling sequence, which is used to determine which device has requested service.

SPD (Serial Poll Disable)—SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Addressed Multiline Commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands. Both the command and the address preceding it are sent with ATN true.

SDC (Selective Device Clear)—The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.

GTL (Go To Local)—The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.

GET (Group Execute Trigger)—The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

Address Commands

Addressed commands include two primary command groups and a secondary address group. ATN is true when these commands are asserted. The commands include:

LAG (Listen Address Group)—These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group)—The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group)—Commands in this group provide additional addressing capabilities. Many devices (including the Model 707) do not use these commands.

Unaddress Commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten)—Listeners are placed in the listener idle state by the UNL command.

UNT (Untalk)—Any previously commanded talkers will be placed in the talker idle state by the UNT command.

Device-Dependent Commands

The purpose of the device-dependent commands will depend on the configuration of the instrument. Generally, these commands are sent as one or more ASCII characters that tell the device to perform a specific function.

The IEEE-488 bus actually treats these commands as data in that ATN is false when the commands are transmitted.

Command Codes

Command codes for the various commands that use the data lines are summarized in Figure C-3. Hexadecimal and the decimal values for the various commands are listed in Table C-2.

Table C-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SCG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical Command Sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table C-3 lists a typical bus sequence for sending the addressed multiline command. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table C-4 gives a typical device-dependent command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the device-dependent command string.

IEEE Command Groups

Command groups supported by the Model 707 are listed in Table C-5. Device-dependent commands are not included in this list.

Table C-3. Typical Addressed Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	2	32	50
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 18.

Table C-4. Typical Device-Dependent Command Sequence

Step	Command	ATN State	Data Bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	2	32	50
3	Data	Set high	R	52	82
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 18.

Table C-5. IEEE Command Group

HANDSHAKE COMMAND GROUP
- DAC=DATA ACCEPTED
- RFD=READY FOR DATA
- DAV=DATA VALID

UNIVERSAL COMMAND GROUP
- ATN=ATTENTION
- DCL=DEVICE CLEAR
- IFC=INTERFACE CLEAR
- LLO=LOCAL LOCKOUT
- REN=REMOTE ENABLE
- SPD=SERIAL POLL DISABLE
- SPE=SERIAL POLL ENABLE

ADDRESS COMMAND GROUP

LISTEN:
- LAG=LISTEN ADDRESS GROUP
- MLA=MY LISTEN ADDRESS
- UNL=UNLISTEN

TALK:
- TAG=TALK ADDRESS GROUP
- MTA=MY TALK ADDRESS
- UNT=UNTALK
- OTA=OTHER TALK ADDRESS

ADDRESSED COMMAND GROUP
- ACG=ADDRESSED COMMAND GROUP
- GTL=GO TO LOCAL
- SDC=SELECTIVE CLEAR

STATUS COMMAND GROUP
- RQS=REQUEST SERVICE
- SRQ=SERIAL POLL REQUEST
- STB=STATUS BYTE
- EOI=END

D_7 D_6 D_5 D_4					X 0 0 0		X 0 0 1		X 0 1 0		X 0 1 1		X 1 0 0		X 1 0 1		X 1 1 0		X 1 1 1	
BITS D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	COLUMN→ ROW↓	0(A)	0(B)	1(A)	1(B)	2(A)	2(B)	3(A)	3(B)	4(A)	4(B)	5(A)	5(B)	6(A)	6(B)	7(A)	7(B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	O	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C	3	S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	0	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		:	
1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SCG)

*PPC (PARALLEL POLL CONFIGURE). PPU (PARALLEL POLL UNCONFIGURE), AND TCT (TAKE CONTROL) NOT IMPLEMENTED BY MODEL 707.

NOTE: D_0 = DIO1 ... D_7 = DIO8
X = DON'T CARE

Figure C-3. Command Codes

APPENDIX D

Equivalent IEEE-488 Commands for Front Panel Keys

Front Panel Key	IEEE-488 Command
MEMORY	E
RELAYS	E
COPY DISPLAY→MEMORY	Z
COPY DISPLAY→RELAYS	Z
INSERT Blank Setup	I
DELETE Setup	Q
MENU Operations:	
View Digital Input	U7
Program Digital Output	O
Select External Trigger	A
Select Matrix Ready	B
Select Stand-alone or Master/Slave Operation	None
Program IEEE-488 Address	None
View Relay (Hardware) Settling Time	U6
View Slot Number and Card Label	U5,u
Execute Self-test	J
Return to Factory Defaults	R
SETTLING TIME (Programmed)	S
MAKE/BREAK Rows	V
BREAK/MAKE Rows	W
TRIGGER Operations:	
ENABLE	F
SOURCE	T
MANUAL	None
RESET	See Note
CLEAR Crosspoint Display	None
OPEN Crosspoint	N
CLOSE Crosspoint	C

Note: A Device Clear (DCL) or Selective Device Clear (SDC) command is the bus equivalent of the RESET key. The associated programmed statements are CLEAR 7 and CLEAR 718.

APPENDIX E

ASCII Character Codes and IEEE-488 Multiline Interface Command Messages

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
0	00	NUL	
1	01	SOH	GTL
2	02	STX	
3	03	ETX	
4	04	EOT	SDC
5	05	ENQ	PPC
6	06	ACK	
7	07	BEL	
8	08	BS	GET
9	09	HT	TCT
10	0A	LF	
11	0B	VT	
12	0C	FF	
13	0D	CR	
14	0E	SO	
15	0F	SI	
16	10	DLE	
17	11	DC1	LLO
18	12	DC2	
19	13	DC3	
20	14	DC4	DCL
21	15	NAK	PPU
22	16	SYN	
23	17	ETB	
24	18	CAN	SPE
25	19	EM	SPD
26	1A	SUB	
27	1B	ESC	
28	1C	FS	
29	1D	GS	
30	1E	RS	
31	1F	US	

* Message sent or received with ATN true.

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
32	20	SP	MLA 0
33	21	!	MLA 1
34	22	"	MLA 2
35	23	#	MLA 3
36	24	$	MLA 4
37	25	%	MLA 5
38	26	&	MLA 6
39	27	'	MLA 7
40	28	(	MLA 8
41	29	)	MLA 9
42	2A	*	MLA 10
43	2B	+	MLA 11
44	2C	,	MLA 12
45	2D	–	MLA 13
46	2E	.	MLA 14
47	2F	/	MLA 15
48	30	0	MLA 16
49	31	1	MLA 17
50	32	2	MLA 18
51	33	3	MLA 19
52	34	4	MLA 20
53	35	5	MLA 21
54	36	6	MLA 22
55	37	7	MLA 23
56	38	8	MLA 24
57	39	9	MLA 25
58	3A	:	MLA 26
59	3B	;	MLA 27
60	3C	<	MLA 28
61	3D	=	MLA 29
62	3E	>	MLA 30
63	3F	?	UNL

* Message sent or received with ATN true. Numbers shown represent primary address resulting in MLA (My Listen Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
64	40	@	MTA 0
65	41	A	MTA 1
66	42	B	MTA 2
67	43	C	MTA 3
68	44	D	MTA 4
69	45	E	MTA 5
70	46	F	MTA 6
71	47	G	MTA 7
72	48	H	MTA 8
73	49	I	MTA 9
74	4A	J	MTA 10
75	4B	K	MTA 11
76	4C	L	MTA 12
77	4D	M	MTA 13
78	4E	N	MTA 14
79	4F	O	MTA 15
80	50	P	MTA 16
81	51	Q	MTA 17
82	52	R	MTA 18
83	53	S	MTA 19
84	54	T	MTA 20
85	55	U	MTA 21
86	56	V	MTA 22
87	57	W	MTA 23
88	58	X	MTA 24
89	59	Y	MTA 25
90	5A	Z	MTA 26
91	5B	[	MTA 27
92	5C	\	MTA 28
93	5D	]	MTA 29
94	5E	∩	MTA 30
95	5F	—	UNT

* Message sent or received with ATN true. Numbers shown are primary address resulting in MTA (My Talk Address).

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
96	60	∩	MSA 0,PPE
97	61	a	MSA 1,PPE
98	62	b	MSA 2,PPE
99	63	c	MSA 3,PPE
100	64	d	MSA 4,PPE
101	65	e	MSA 5,PPE
102	66	f	MSA 6,PPE
103	67	g	MSA 7,PPE
104	68	h	MSA 8,PPE
105	69	i	MSA 9,PPE
106	6A	j	MSA 10,PPE
107	6B	k	MSA 11,PPE
108	6C	l	MSA 12,PPE
109	6D	m	MSA 13,PPE
110	6E	n	MSA 14,PPE
111	6F	o	MSA 15,PPE
112	70	p	MSA 16,PPD
113	71	q	MSA 17,PPD
114	72	r	MSA 18,PPD
115	73	s	MSA 19,PPD
116	74	t	MSA 20,PPD
117	75	u	MSA 21,PPD
118	76	v	MSA 22,PPD
119	77	w	MSA 23,PPD
120	78	x	MSA 24,PPD
121	79	y	MSA 25,PPD
122	7A	z	MSA 26,PPD
123	7B	{	MSA 27,PPD
124	7C	|	MSA 28,PPD
125	7D	}	MSA 29,PPD
126	7E	~	MSA 30,PPD
127	7F	DEL	

*Message send or received with ATN true. Numbers represent secondary address values resulting in MSA (My Secondary Address).

APPENDIX F

Glossary of Terms

The following terms are defined to clarify or expand on how they relate specifically to the material of this instruction manual.

Actuation Time — The time between application of the nominal relay coil voltage and the final closure of the relay contacts after the contact bounce interval.

Bandwidth — The range of frequencies that can be switched, conducted, or amplified within certain limits. Under given load conditions, bandwidth is defined by the −3dB (half-power) points.

BNC — A type of coaxial connector used in situations requiring shielded cable for signal connections.

Break-Before-Make — Disconnecting the present circuit before connecting a new circuit. Also known as Break/Make.

Carry Current — The maximum continuous current of closed relay contacts. Most relays are rated higher for carry current than switched current. (Heat is generated by I^2R losses for carry current and I^2R losses plus arcing for switched current.)

Channel — One of several signal paths on a switching card. For scanner (or multiplex) cards, the channel is used as a switched input in measuring circuits or as a switched output in sourcing circuits. For switch cards, each channel's signal paths are independent of other channels. For matrix cards, a channel is established by the actuation of a relay at a row and column crosspoint. Also see Path.

Channel Crosstalk — Coupling of a signal from one channel to another or to the output by conduction or radiation. Crosstalk is expressed in decibels at a specified load and up to a specific frequency.

Channel Isolation — On a switching card, the isolation from signal HI and LO of one channel to signal HI and LO of any other channel (or the output on switch or scanner cards). Specified as resistance and capacitance, except for RF cards (decibels and frequency range). Also see Path Isolation.

Coaxial Cable — A cable that has one conductor completely surrounding the other, the two being coaxial and separated by an insulator.

Coil Drop-Out Voltage — See Relay Must-Release Value.

Coil Pull-In Voltage — See Relay Must-Operate Value.

Coil Resistance — A nominal value of the resistance of the coil winding at a specified ambient temperature.

Cold Junction — The junction in a thermocouple circuit that is held at a stable known temperature. Also known as reference junction.

Cold Switching — Closing the relay contacts before applying voltage and current and removing voltage and current before opening the contacts. (Contacts do not make or break current.) Also see Dry Circuit Switching.

Column — As viewed on the schematic of a matrix card, the vertical signal lines or a vertical group of relays.

Common Mode — Between two signal lines and a third (e.g. from signal HI and LO to chassis ground or guard).

Common Mode Input Isolation — On a switching card, the isolation from signal HI and LO to guard (or shield) for a 3-pole circuit, or from signal HI and LO to chassis ground for a 2-pole circuit. Specified as resistance and capacitance.

Common Mode Rejection Ratio — The ability of an instrument to reject interference from a common voltage at its input terminals with respect to ground. Usually expressed in decibels at a frequency.

Common Mode Voltage — A voltage between input low and chassis ground of an instrument.

Contact Bounce — The intermittent and undesired opening of relay contacts during closure, or closing of relay contacts during opening.

Contact Combination — The total assembly of contacts on a relay. Sometimes used for contact form.

Contact Form — A single-pole contact assembly.

Contact Life — The maximum number of expected closures before failure. Life is dependent on the switched voltage, current, and power. Failure is usually when the contact resistance exceeds an end of life value.

Contact Offset Voltage — See Contact Potential.

Contact Potential — A voltage produced between contact terminals due to the temperature gradient across the relay contacts, and the reed-to-terminal junctions of dissimilar metals. (The temperature gradient is typically caused by the power dissipated by the energized coil.) Also known as contact offset voltage, thermal EMF, and thermal offset.

Contact Rating — The voltage, current, and power capacities of relay contacts under specified environmental conditions. See Carry Current and Switched Current.

Contact Resistance — For a relay, the resistance in ohms across closed contacts. For a Keithley switching card, also includes the tape resistance and connector terminal resistance. Also see Path Resistance.

Contacts — The surfaces of current carrying elements where electric circuits are opened or closed.

Crosspoint — The intersecting point of a column and row in a relay matrix. Specified as (column, row) or (row,column). A crosspoint consists of one or more poles of Form A (normally open) relay switching.

Crosstalk — See Channel Crosstalk.

Current Surge Limiting — The circuitry necessary to protect relay contacts from excessive current caused by capacitive loads.

Daisy Chaining — The serial connection of two or more mainframes in a master/slave(s) configuration. Also, some switching cards (e.g. low current) can be daisy-chained to yield more inputs.

Differential Input Isolation — On a switching card, the isolation from signal HI to LO. Specified as resistance and capacitance.

Digital I/O — A TTL-level input/output port that is programmable by the mainframe.

Drive Current — The amount of current necessary to energize a relay. Sometimes specified per channel or per card.

Dry Circuit Switching — Switching below specified levels of voltage (e.g. 20mV) and current to minimize any physical and electrical changes in the contact junction. Also see Cold Switching.

Dry Reed Relay — A glass-enclosed, hermetically sealed, magnetically actuated contact. No mercury or other wetting material is used.

DUT — An abbreviation for Device Under Test. Also see UUT (Unit Under Test).

Electrochemical Effects — The property that generates current between circuit board conductors due to contamination of the card surface. Minimized with proper handling and cleaning.

Electromechanical Relay — A relay that uses an electromagnet to move an armature thereby actuating current.

EMI — Abbreviation for Electromagnetic Interference. A term that defines unwanted electromagnetic radiation from a device which could interfere with desired signals in test or communication equipment, for example. RFI (Radio Frequency Interference) and EMI are often used interchangeably.

Floating — The condition where a common mode voltage exists between earth ground and the instrument or circuit of interest. (Low of circuit is not at earth potential.)

Form — see Contact Form.

Form A — "Make" or single-throw, normally-open contact configuration. Single pole configuration also called SPST-NO. A 2-pole configuration is called 2 Form A.

Form B — "Break" or single-throw, normally-closed contact configuration. Single pole configuration also called SPST-NC. A 2-pole configuration is called 2 Form B.

Form C — "Break and make" or double-throw contact configuration. A 2-pole configuration is called 2 Form C or DPDT.

Guarding — A technique that reduces leakage errors and decreases response time. Consists of a guard conductor driven by a low-impedance source surrounding the lead of a high-impedance signal. The guard voltage is kept at or near the potential of the signal.

Hot Junction — The junction of two dissimilar metals in a thermocouple circuit that is used to measure an unknown temperature. Also known as measurement junction.

IEEE (Digital) Common Isolation — On a switching card, the isolation from signal HI and LO to digital common for a 3-pole circuit, or from signal HI to digital common for a 2-pole circuit. Primarily due to the relay coil to contact impedance, it is specified as resistance and capacitance.

Input Isolation — On a switching card, the isolation from signal HI to LO (or guard) for a 2-pole circuit. Specified as resistance and capacitance.

Insertion Loss — The attenuation of signals due to routing them through a switching card. Specified as a decibel value over a frequency range.

Insulation Resistance — The ohmic resistance of insulation. It degrades quickly as humidity increases.

I/O — Abbreviation for input/output, which refers to the transmission of information to an external device (output), and the reception of information from an external device (input).

Isothermal Block — The metal block that equalizes the temperature of all thermocouple connections.

Leakage Current — Error current that can degrade sensitive measurements. Even high resistance paths between low current conductors and nearby voltage sources can generate significant leakage currents.

Low Noise Cable — A cable that is coated with a conductive layer between the braid and inner insulator (coax and triax) and under the inner shield (triax). This reduces triboelectric currents caused by friction due to vibration, movement, or temperature fluctuation.

Mainframe — A switching instrument that operates according to user commands to connect signals among sourcing and measuring instruments and devices under test. A mainframe is also frequently referred to as a scanner, multiplexer, matrix, or programmable switch.

Make-Before-Break — Connecting a new circuit before disconnecting the present circuit. Also known as Make/Break.

Master — A scanner mainframe that has control of other mainframes (slaves) in a serial chain. A master/slave combination has one bus address and appears as one mainframe with increased capacity.

Matrix — Connecting multiple inputs to multiple outputs.

Matrix Card — A type of card with a switching configuration that has columns and rows of relay crosspoints. (Also called a coordinate switch.) With a matrix card, since any one point can be connected to any other, you can simultaneously have one input with multiple outputs, multiple inputs with one output, or multiple inputs with multiple outputs.

Mercury Wetted Relay — A reed relay in which the contacts are wetted by a film of mercury. Usually has a required operating position to avoid liquid mercury shorting the contacts; other types are position insensitive.

Multiplex — Connecting one instrument to multiple devices under test or multiple instruments to one device under test. Also see Scan.

Multiplex Card — See Scanner Card.

Noise — Any unwanted electronic signal.

Normally Closed Contacts — A contact pair that is closed when the relay is not energized.

Normally Open Contacts — A contact pair that is open when the relay is not energized.

Normal Mode — Between two signal lines (e.g. from signal HI to LO).

Normal Mode Rejection Ratio — The ability of an instrument to reject interference (usually of line frequency) across its input terminals. Usually expressed in decibels at a frequency.

Normal Mode Voltage — A voltage applied between the input high and input low terminals of an instrument.

Offset Current — A current that comes from a switching card even though no user signals are applied. It comes mostly from the finite coil to contact impedance. It is also generated by triboelectric, piezoelectric, and electrochemical effects present on the card.

Operate Time — See Actuation Time.

Path — One of many signal paths on a matrix switching card. A path is established by the actuation of a relay at a row and column crosspoint. Also see Channel.

Path Isolation — On a matrix switching card, the isolation from signal HI and LO of one path to signal HI and LO of any other path. Specified as resistance and capacitance. Also see Channel Isolation.

Path Resistance — On a matrix switching card, the resistance per conductor of a closed path, including the tape resistance and connector terminal resistance. Also see Contact Resistance.

Piezoelectric Currents — The current caused by mechanical stress to the insulating materials or connectors. To minimize, the stress is removed from the insulators, and materials with low piezoelectric effect are used.

Pole — A combination of mating contacts: normally open, normally closed, or both.

Propagation Delay — The specified amount of time for a signal to be routed through a previously closed channel of a switching card. The delay must be considered, for example, when the switched signal is used to synchronize other signals.

Reed Relay — A relay using one or more glass-enclosed, hermetically sealed, magnetically actuated contact members. Some types are dry to improve isolation or make them position independent. Some types are mercury wetted to improve switched current rating and make contact resistance more predictable. Also see electromechanical relay and solid state relay.

Reference Channel — On a thermocouple scanner card, the channel that measures the temperature of the isothermal block and converts it to a cold junction voltage for the other channels.

Reference Output — On a thermocouple scanner card, the output signal representing the temperature of the reference channel, usually the isothermal block.

Relay — An electrically controlled mechanical device that opens and closes electrical contacts. A relay provides isolation of control signals from switched signals.

Relay Drive — The total current available from the power supply of the mainframe to energize the relay coils on switching cards. This current is derated at elevated temperatures.

Relay Just-Operate Value — The measured functioning value at which a particular relay operates.

Relay Just-Release Value — The measured functioning value for the release of a particular relay.

Relay Must-Operate Value — A specified functioning value at which all relays meeting the specification must operate. Also known as relay pick-up or pull-in value.

Relay Must-Release Value — A specified functioning value at which all relays meeting the specification must release. Also known as relay drop-out value.

Relay Setup — A configuration of open and closed relays.

Release Time — The time between the removal of the coil voltage and the stabilized opening of the contacts.

Row — As viewed on the schematic of a matrix card, the horizontal signal lines or a horizontal group of relays.

Scan — Sequential connecting (usually break-before-make) of one instrument to multiple devices under test or multiple instruments to one device under test. Also see Multiplex.

Scanner Card — A type of switching card where one input is routed to one of several outputs (e.g. sourcing), or one of several inputs is routed to one output (e.g. measuring). The actual switching can be nonsequential (multiplex) or sequential (scan). Also known as a multiplex card.

Settle Time — The time required for establishing relay connections and stabilizing user circuits.

Shielding — A metal enclosure for the circuit being measured or a metal sleeving surrounding wire conductors (coax or triax cable) to lessen interference, interaction, or current leakage. The shield is usually grounded.

Slave — A mainframe that is serially connected to a controlling mainframe (master). The slave is controlled from the master. A master/slave combination has one bus address and appears as one mainframe with increased capacity.

Solid State Relay — A relay that switches electric circuits by use of semiconductor elements without moving parts or conventional contacts.

Standoff Potential — The breakdown voltage across relay contacts.

Switch — Connecting one input to one output. Also known as actuate.

Switch Card — A type of card with independent and isolated relays for switching inputs and outputs on each channel. This configuration is more flexible than a scanner (multiplex) card.

Switched Current — The maximum current level that can be reliably handled while opening and closing contacts. Also see Carry Current.

Switching Cards — The general classification of relay cards. May be subdivided into: switch cards (1 input to 1 output), scanner or multiplex cards (1:N, N:1), and matrix cards (M:N).

Temperature Offset — On a thermocouple scanner card, the maximum temperature difference between any two channels on the card's isothermal block.

Test Fixture — An enclosure, sometimes shielded, used for mounting single or multiple devices for testing purposes.

Thermal EMF — See Contact Potential.

Thermal Offset Voltage — See Contact Potential.

Triaxial Cable — A cable with three conductors: one conductor surrouded by an inner shield and an isolated outer shield. Generally, the inner shield is connected to signal LO and the outer shield to power-line ground. If guarding is used, the inner shield is connected to guard potential and the outer shield to signal LO or ground. Also see Guarding.

Triboelectric Current — The current caused by friction between a conductor and insulator when a cable flexes due to vibration, movement, or temperature fluctuation. Also see Low Noise Cable.

Trigger — An external stimulus that initiates one or more instrument functions. Trigger stimuli include: the front panel, an external trigger pulse, and IEEE-488 bus X, Talk, and GET triggers.

UUT — An abbreviation for Unit Under Test. Also see DUT (Device Under Test).

Voltage Clamping — The circuitry necessary to protect relay contacts from excessive voltage caused by switching current into inductive loads.

VSWR — Abbreviation for Voltage Standing Wave Ratio. For a switching card, the loss due to the mismatch introduced into the signal by the card contacts and conductors. Expressed as a ratio of the highest voltage to the lowest voltage found in the signal.

For further reading on switching terminology, see the following references:

ANSI/EIA RS-473-1981. Definitions and Terminology for Relays for Electronic Equipment. American National Standards Institute, 1981.

ANSI/IEEE Std. 100-1984. IEEE Standard Dictionary of Electrical and Electronics Terms. 3rd edition. Institute of Electrical and Electronics Engineers, 1984.

Engineers' Relay Handbook. 3rd edition. National Association of Relay Manufacturers, 1980.

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MODEL 707
DEVICE-DEPENDENT COMMANDS

External Trigger	
A0	Falling edge triggers Model 707
A1	Rising edge triggers Model 707

Matrix Ready	
B0	Negative true Matrix Ready output
B1	Positive true Matrix Ready output

Close Crosspoint	
Crc(,rc)...(,rc)	Close crosspoints of setup indicated by edit pointer (rows A-H, cols. 1-360)

Display	
Dccccccccccccc	Display ASCII characters (14 max.)
DX	Return alphanumeric display to normal

Edit Pointer	
E0	Point to current relay setup
En	Point to stored relay setup (1-100)

Enable/Disable Triggers	
F0	Disable triggers
F1	Enable triggers

Data Format	
G0	Full output, all data in one talk
G1	Full output, one mainframe row per talk
G2 or G3	Inspect output, all data in one talk
G4	Condensed output, all data in one talk
G5	Condensed output, one mainframe per talk
G6	Binary output, all data in one talk
G7	Binary outut, one mainframe per talk

Hit Key	
Hn	Emulate front panel key press (1-41)

Insert Blank Setup	
In	Insert blank setup in memory (1-100)

Self-test	
J0	Perform self-test

EOI and Hold-off	
K0	Send EOI, hold-off on X until Ready
K1	No EOI, hold-off on X until Ready
K2	Send EOI, do not hold-off on X
K3	No EOI, do not hold-off on X
K4	Send EOI, hold-off on X until Matrix Ready
K5	No EOI, hold-off on X until Matrix Ready

Download Setups	
Lbbb...X	Download setups from controller to Model 707

SRQ	
M0	SRQ disabled
M1	not used
M2	Front panel key press
M4	Digital I/O interrupt
M8	Matrix Ready
M16	Ready for trigger
M32	Error
M128	not used

Open Crosspoint	
Nrc(,rc)...(,rc)	Open crosspoints of setup indicated by edit pointer (rows A-H, cols. 1-360)

Digital Output	
Onnn	Set states of digital output lines (000-255)

Clear Crosspoints	
P0	Open all crosspoint relays
Pn	Clear all crosspoints of stored setup (1-100)

Delete Setup	
Qn	Delete setup from memory (1-100)

Restore Defaults	
R0	Restore factory defaults

Programmed Settling Time	
Sn	Program settling time in msec (0-65000)

Trigger	
T0 or T1	Trigger on talk
T2 or T3	Trigger on GET
T4 or T5	Trigger on X
T6 or T7	Trigger on External Trigger pulse
T8 or T9	Trigger on front panel MANUAL key only

Status	
U0	Send machine status word
U1	Send error status word
U2,n	Output setup "n" (0-100) with current G format
U3	Send RELAY STEP pointer
U4	Send number of slaves
U5,u	Send model number of each card in unit "u" (0-4)
U6	Send relay settling time
U7	Send digital input of unit
U8	Send RELAY TEST input

Make/Break	
Vabcdefgh	Select rows for make/break operation (00000000 - 11111111)

Break/Make	
Wabcdefgh	Select rows for break/make operation (00000000 - 11111111)

Execute	
X	Execute commands

Terminator	
Y0	<CR><LF>
Y1	<LF><CR>
Y2	<CR>
Y3	<LF>

Copy Setup	
Z0,n	Copy current relay setup to memory location "n" (1-100)
Zn,0	Copy setup from memory location "n" (1-100) to relays
Zm,n	Copy setup from location "m" (0-100) to location "n" (0-100)

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SERVICE FORM

Model No. _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

Name _____ **Phone** _____

Company _____

Address _____

City _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.) _____

What power line voltage is used? _____ Variation? _____

Frequency? _____ Ambient Temperature? _____ °F.

Variation? _____ °F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

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Model 7071 Addendum

The following change information is supplied as a supplement to this manual in order to provide the user with the latest improvements and corrections in the shortest possible time. It is recommended that this information be placed at the end of Section 4 of the matrix card instruction manual.

Copper cladding has been added to the rear shield of the matrix card in order to provide increased protection from static discharge. The copper shield is electrically connected to chassis ground of the matrix card by a jumper wire.

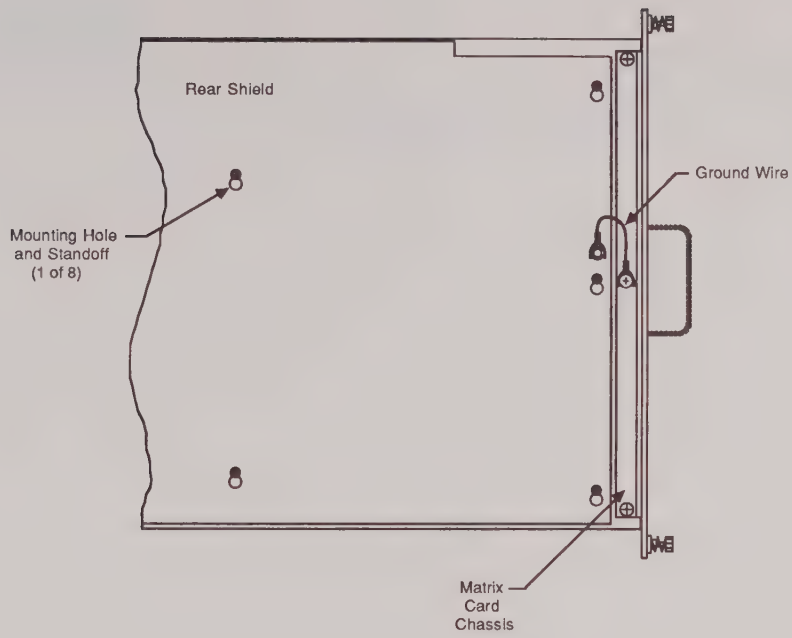
In order to service the matrix card, it may be necessary to remove the rear shield. Referring to the illustration, perform the following procedure to remove and reinstall the rear shield:

1. Disconnect the jumper wire from the matrix card chassis. The wire is secured to the matrix card chassis with a screw.
2. The rear shield is secured to the matrix card by eight standoffs. Carefully slide the rear shield upward until the eight standoffs align with the large clearance holes in the shield and remove the shield.
3. To reinstall the shield, reverse the above procedure. Make sure the metal side of the shield is facing outward.

CAUTION

Failure to observe the following precautions could result in damage not covered by the warranty:

1. **The shield must be installed such that the metal side is facing away from the matrix card. Backward installation will cause PC board connections to short out against the metal shield.**
2. **The jumper wire must be connected as shown in order to provide circuit protection from static discharge.**


Rear Shield
Ground Wire
Mounting Hole
and Standoff
(1 of 8)
Matrix
Card
Chassis

KEITHLEY

Model 7071 General Purpose Matrix Card Instruction Manual

Contains Operating and Servicing Information

Publication Date: March 1988
Document Number: 7071-901-01 Rev. B

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Keithley Instruments, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

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Instruction Manual
Model 7071
General Purpose Matrix Card

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Instruments Division
Cleveland, Ohio, U.S.A.
Document Number: 7071-901-01

SAFETY PRECAUTIONS

The following safety precautions should be observed before using the Model 7071 and the associated instruments.

This matrix card is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over this manual carefully before using the matrix card.

Exercise extreme caution when a shock hazard is present at the test circuit. User-supplied lethal voltages may be present on the card connector jacks. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS or 42.4V peak are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Do not exceed 200V between any two pins or between any pin and earth ground.

Inspect the connecting cables and test leads for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the test cables or any instruments while power is applied to the circuit under test. Turn off the power and discharge any capacitors before connecting or disconnecting cables from the matrix card.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

Do not exceed the maximum allowable input of the matrix card, as defined in the specifications and operation section of this manual.

SPECIFICATIONS

MATRIX CONFIGURATION:
8 rows by 12 columns.

CROSSPOINT CONFIGURATION:
3-pole Form A.

CONNECTOR TYPE: Quick disconnect using 38 pin connectors or screw terminals (HI, LO, Guard).

MAXIMUM SIGNAL LEVEL: 200V, 1A carry/0.5A switched, 10VA peak (resistive load).

COMMON MODE VOLTAGE: 200V maximum between any 2 pins or chassis.

CONTACT LIFE:

Cold Switching: 10^8 closures.

At Maximum Signal Level: 10^5 closures.

PATH RESISTANCE (per conductor): $<0.5\Omega$ initial, $<1.5\Omega$ at end of contact life.

CONTACT POTENTIAL: $<5\mu V$ per crosspoint (HI to LO).

OFFSET CURRENT: $<100pA$.

ISOLATION:

Path (1MHz, 1MΩ load): $>10^{10}\Omega$, $<10pF$, $>40dB$.

Differential: $10^9\Omega$, 45pF nominal.

Common Mode: $10^9\Omega$, 165pF nominal.

INSERTION LOSS (1MHz, 50Ω source, 1MΩ load): 0.1dB typical.

3dB BANDWIDTH (1MΩ load): 5MHz typical.

RELAY DRIVE CURRENT (per crosspoint): 15mA.

RELAY SETTLING TIME: $<3ms$.

ENVIRONMENT:

Operating: 0° to 50°C, up to 35°C at 70% R.H.

Storage: −25 to +65°C.

ACCESSORY SUPPLIED: Instruction manual

ACCESSORIES AVAILABLE:

Model 7078-CIT: Contact Insertion and Extraction Tools

Model 7078-HCT: Hand Crimping Tool

Model 7078-KIT: Connector Kit.

Model 7078-MTC: Mass Terminated Cable Assembly, 6m (20 ft.)

Specifications subject to change without notice.

Contains information on Model 7071 features, specifications, and accessories.

SECTION 1
General Information

Details installation of the Model 7071 General Purpose Matrix Card within the Model 707 Switching Matrix, covers card connections, and also discusses basic matrix configurations and matrix expansion.

SECTION 2
Operation

Gives two typical applications for the Model 7071, including thick film resistor network testing and transistor testing.

SECTION 3
Applications

Contains performance verification procedures, troubleshooting information and principles of operation for the matrix card.

SECTION 4
Service Information

Lists replacement parts, and also includes component layout and schematic drawings for the Model 7071.

SECTION 5
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SECTION 1
General Information

1.1 INTRODUCTION

This section contains general information about the Model 7071 General Purpose Matrix Card and is arranged in the following manner:

1.2 Features
1.3 Warranty Information
1.4 Manual Addenda
1.5 Safety Symbols and Terms
1.6 Specifications
1.7 Unpacking and Inspection
1.8 Repacking for Shipment
1.9 Optional Accessories

1.2 FEATURES

The Model 7071 is a general purpose, three-pole 8 × 12 (8 row by 12 column) matrix card. Some of the key features include:

- Guard capability. Each HI/LO path pair on the PC board is surrounded by a third path that can be used for guarding.
- Low contact potential and offset current for minimal effects on low-level signals.
- Quick disconnects using the "rack and panel" receptacles on the rear panel or terminal blocks on the PC board.

1.3 WARRANTY INFORMATION

Warranty information is located on the inside front cover of this instruction manual. Should your Model 7071 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the matrix card for repair, be sure to fill out and include the service form at the back of this manual in order to provide the repair facility with the necessary information.

1.4 MANUAL ADDENDA

Any improvements or changes concerning the matrix card or manual will be explained in an addendum included with the unit. Be sure to note these changes and incorporate them into the manual.

1.5 SAFETY SYMBOLS AND TERMS

The following symbols and terms may be found on an instrument or used in this manual.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the matrix card. Such damage may invalidate the warranty.

1.6 SPECIFICATIONS

Model 7071 specifications may be found at the front of this manual. These specifications are exclusive of the matrix mainframe specifications.

1.7 UNPACKING AND INSPECTION

1.7.1 Inspection for Damage

The Model 7071 is packaged in a resealable, anti-static bag to protect it from damage due to static discharge and from contamination that could degrade its performance. Before removing the card from the bag, observe the following precautions on handling.

Handling Precautions:

1. Always grasp the card by the handle and side edges. Do not touch the edge connectors and do not touch board surfaces or components.
2. When not installed in a Model 707 mainframe, keep the card in the anti-static bag and store in the original packing carton.

After removing the card from its anti-static bag, inspect it for any obvious signs of physical damage. Report any such damage to the shipping agent immediately.

If you are going to install the card in the Model 707 mainframe at this time, be sure to follow the additional handling precautions explained in paragraph 2.2

1.7.2 Shipping Contents

The following items are included with every Model 7071 order:

- Model 7071 General Purpose Matrix Card.
- Model 7071 Instruction Manual.
- Additional Accessories as ordered. Note that the Model 7078-MTC may be shipped in a separate packing carton.

1.7.3 Instruction Manual

The Model 7071 Instruction Manual is three-hole drilled so that it can be added to the three-ring binder of the Model 707 Switching Matrix Instruction Manual. After removing the plastic wrapping, place the manual in the binder after the mainframe instruction manual. Note that a manual identification tab is included and should precede the matrix card instruction manual.

If an additional instruction manual is required, order the manual package, Keithley part number 7071-901-00. The manual package includes an instruction manual and any pertinent addenda.

1.8 REPACKING FOR SHIPMENT

Should it become necessary to return the Model 7071 for repair, carefully pack the unit in its original packing carton or the equivalent, and include the following information:

- Advise as to the warranty status of the matrix card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.9 OPTIONAL ACCESSORIES

The following accessories are available for use with the Model 7071.

Model 7078-CIT Contact Insertion and Extraction Tools

The Model 7078-CIT contains an insertion tool that is used to insert wire crimp tail contacts into "rack and panel" plugs and receptacles. Conversely, the extraction tool is used for the removal of the contacts.

Model 7078-HCT Hand Crimping Tool

The Model 7078-HCT is used to attach wire crimp tail contacts to #18 to #26 AWG stranded wire.

Model 7078-KIT Connector Kit

The Model 7078-KIT contains the parts to assemble one "rack and panel" plug. This plug will mate to either the ROWS or COLUMNS receptacle on the rear panel of the card. Parts contained in the kit include the plug, plug housing and 40 wire crimp tail contacts.

Model 7078-MTC Mass Terminated Cable Assembly

The Model 7078-MTC is a 20-foot, 36-conductor cable terminated with a "rack and panel" plug on both ends. This cable connects to either the ROWS or COLUMNS receptacle on the rear panel of the card. This cable is commonly cut in half to provide two separate cables. The cables can then be used to connect to both the ROWS and COLUMNS receptacles. The unterminated ends of the cables are then connected to instrumentation and DUTs.

CS-593 Receptacle

One "rack and panel" receptacle that will mate to either the Model 7078-MTC cable or the plug in the Model 7078-KIT connection kit. Requires 36 wire crimp tail contacts (see CS-426).

CS-426 Wire Crimp Tail Contact

Contact for "rack and panel" plug or receptacle. Use Model 7078-HCT to connect wires to contacts.

CS-570-3 Quick Disconnect Terminal Block

Three-terminal block accomodating up to 16 AWG wires. Mates to matrix board pin terminals.

SECTION 2
Operation

2.1 INTRODUCTION

This section contains information on aspects of matrix card operation and is arranged as follows:

2.2 Handling Precautions: Details precautions that should be observed when handling the matrix card to ensure that its performance is not degraded due to contamination.

2.3 Card Installation and Removal: Covers the basic procedure for installing and removing the card from the Model 707 Matrix.

2.4 Basic Matrix Configurations: Explains some the basic ways that a matrix can be used to source or measure. Covers single-ended switching, differential (floating) switching, sensing, shielding, and guarding.

2.5 Connections: Discusses the various methods and techniques that can be used to connect DUTs and instrumentation to the matrix card.

2.6 Matrix Expansion: Discusses the various matrix configurations that are possible by using multiple cards. The significance of the Model 707 backplane row jumpers on matrix configurations is also covered here.

2.7 Typical Connection Schemes: Provides examples of external connections for single card, multiple card and multiple mainframe systems.

2.2 HANDLING PRECAUTIONS

To maintain high impedance isolation, care should be taken when handling the matrix card to avoid contamination from such foreign materials as body oils. Such contamination can substantially lower leakage resistances, degrading performance.

To avoid possible contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card and do not touch board surfaces or components. On "rack and panel" connectors and quick-disconnect terminal blocks, do not touch areas adjacent to the electrical contacts.

CAUTION

Do not store the card by leaning it against an object (such as a wall) with its edge connectors in contact with a contaminated surface (such as the floor). The edge connectors will become contaminated, and tapes and solder connections on the PC board may break as the card bends. ALWAYS store the card (in its anti-static bag) in the original shipping carton.

Dirt build-up over a period of time is another possible source of contamination. To avoid this problem, operate the mainframe and matrix card only in a clean environment.

If the card becomes contaminated, it should be thoroughly cleaned as explained in paragraph 4.2.

2.3 CARD INSTALLATION AND REMOVAL

Connections to the matrix card make it awkward to install/remove the card in the mainframe. Thus, it is advisable to install the card and then make connections to it. Conversely, cables and wires should be disconnected before removing the card from the mainframe.

Referring to Figures 2-1 and 2-2, perform the following procedure to install the Model 7071 matrix card in the Model 707:

1. Turn the Model 707 off.
2. Select a slot in the mainframe and remove the cover plate. The cover plate is fastened to the mainframe chassis with two screws. Retain the cover plate and screws for future use.
3. With the relay side of the matrix card facing towards the fan, feed the card into the slot such that the top and bottom card edges seat into the the card edge guides of the mainframe. Slide the matrix card approximately ⅔ of the way into the mainframe.
4. If using quick-disconnect terminal blocks to make connections, perform the following steps. Otherwise, proceed to step 5.

WARNING

To avoid electrical shock which could result in injury or death, make sure all power is off and stored energy in external circuitry is discharged before making any connections to the matrix card.

A. There are two cable clamps on the rear panel of the matrix card that serve as strain reliefs for terminal block wires. Loosen the two screws of each cable clamp and remove the top half of each clamp.

B. Install the pre-wired terminal blocks (see paragraph 2.5.2) on the matrix card. Make sure the pins on the card are properly mated to the terminal blocks.

C. Route the wires through the rear panel cable clamps. Make sure there is some slack in the wires between the terminal blocks and the clamps before tightening the clamps.

5. Slide the matrix card all the way into the mainframe and tighten the two spring loaded panel fastenters.

WARNING

The mounting screws must be secured to ensure a proper chassis ground connection between the card and the mainframe. Failure to properly secure this ground connection may result in personal injury or death due to electric shock.

NOTE

If using the terminal blocks, leave enough slack in the external cabling so that the card can slide out far enough to gain access to the connections.

6. To remove the card from the mainframe make sure the Model 707 is off, power is removed from external circuitry, and then reverse the above procedure.

2.4 BASIC MATRIX CONFIGURATIONS

A simplified schematic of the Model 7071 8 × 12 matrix card is shown in Figure 2-3. Each of the 96 crosspoints is made up of a three-pole switch. In this simple configuration, any row can be connected to any column by closing the appropriate crosspoint switch. The columns of every Model 7071 matrix card are numbered 1 through 12. However, the actual column numbers of the matrix are determined by which mainframe slot the card is installed in. For example, the columns of a matrix card installed in slot 4 of the mainframe are numbered 37 through 48. Column number assignments for all six mainframe slots are listed in Table 2-1.

Table 2-1. Column Number Assignments

7071 Card Location	Matrix Column Numbers
Slot 1	1 through 12
Slot 2	13 through 24
Slot 3	25 through 36
Slot 4	37 through 48
Slot 5	49 through 60
Slot 6	61 through 72

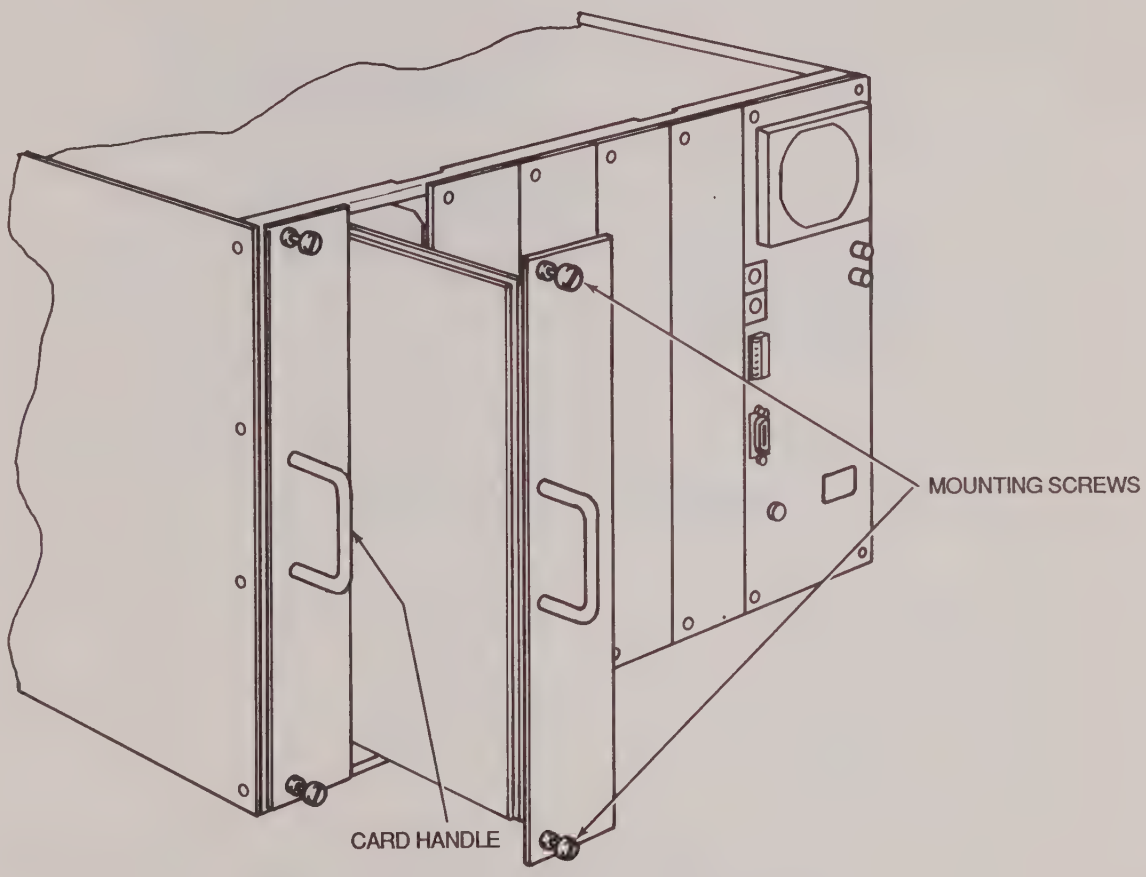


Figure 2-1. Matrix Card Installation

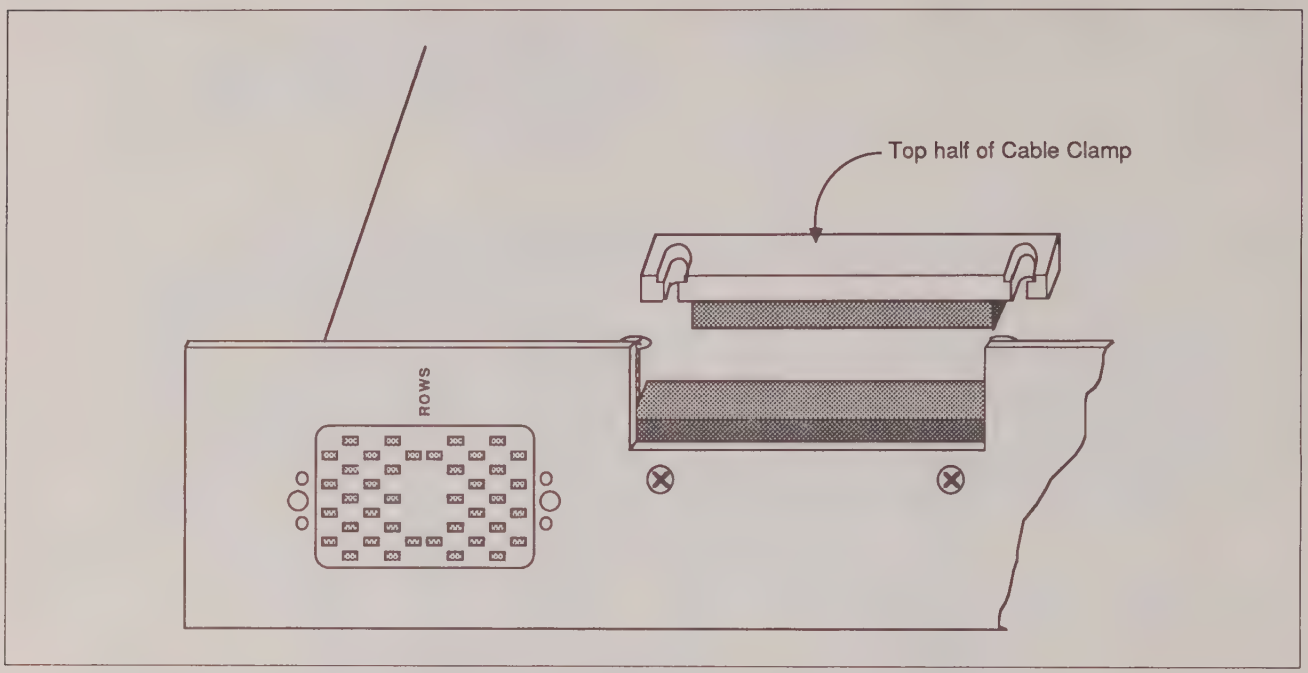


Figure 2-2. Cable Clamp Assembly

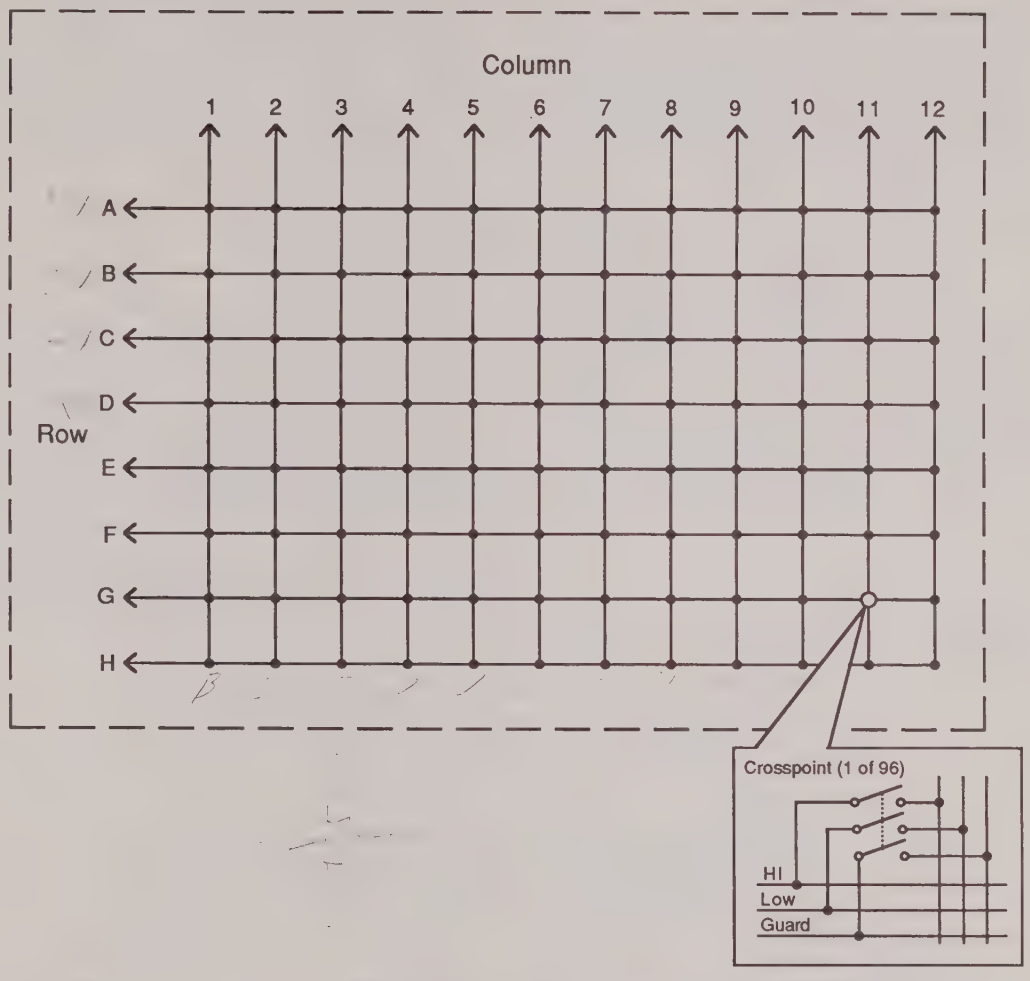


Figure 2-3. Simplified Schematic of Model 7071

2.4.1 Single-Ended Switching

In the single-ended switching configuration, the source or measure instrument is connected to the DUT through a single pathway as shown in Figure 2-4. Note that in the illustration that the matrix card guard (G) is used as a shield as well as circuit low. The matrix card guard is used as the shield because its PC board trace physically surrounds the high (H) and low (L) traces.

2.4.2 Differential Switching

The differential or floating switching configuration is shown in Figure 2-5. The advantage of using this configuration is that the terminals of the source or measure instrument are not confined to the same matrix crosspoint. Each terminal of the instrument can be connected to any of the 96 matrix crosspoints. Again, the guard terminals of the matrix card are used as a shield.

2.4.3 Guarding

Figure 2-6 shows how the matrix card can be used with a driven guard. Since the driven guard is at virtually the same potential as signal high, protection from possible hazardous voltages (up to 200V) must be provided. Many instruments have the capability of configuring its input or output such that a driven guard is placed on the inner shield of a triax connector. The outer shield, connected to common, provides protection from the guard voltage. When making connections from the matrix card to the DUT, make sure that a safety shield is used as shown in the illustration.

2.4.4 Sensing

Figure 2-7 shows how the matrix card can be configured to use instrumentation that have sensing capability. The main advantage of using sensing is to cancel the effects of matrix card path resistance (<1.5Ω) and the resistance of external cabling. Whenever path resistance is a consideration, sensing should be used. In the illustration, matrix card guard is again used as a shield. In a system where a driven guard is required, matrix card guard (G) can be disconnected from circuit LO and connected to the guard potential. However, make sure that the guard is adequately insulated to prevent possible electrical shock, or use quadrax cables using the outer shield as a grounded safety shield.

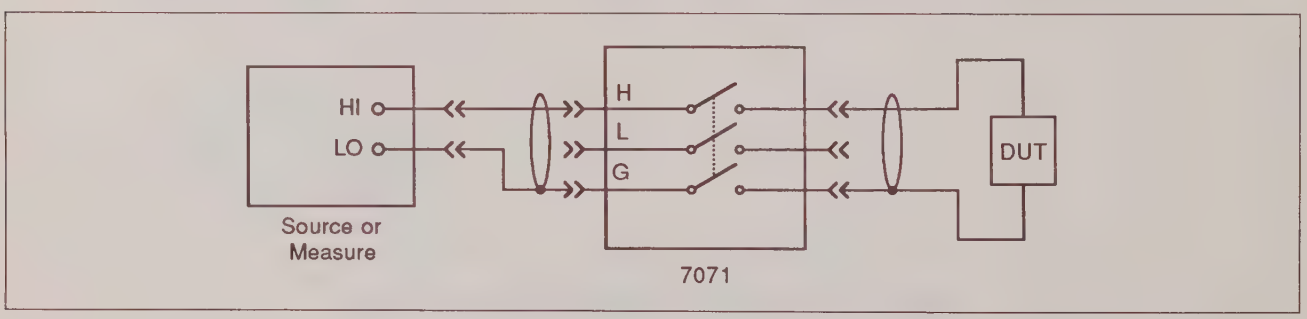


Figure 2-4. Single-Ended Switching Example (Guard Used as Shield)

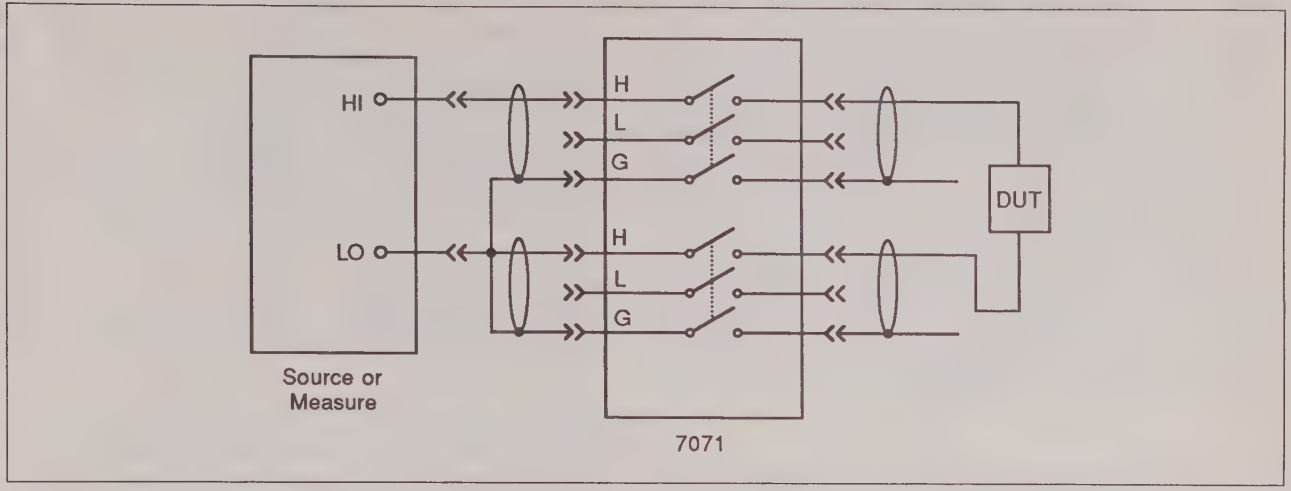


Figure 2-5. Differential Switching Example (Shielded)

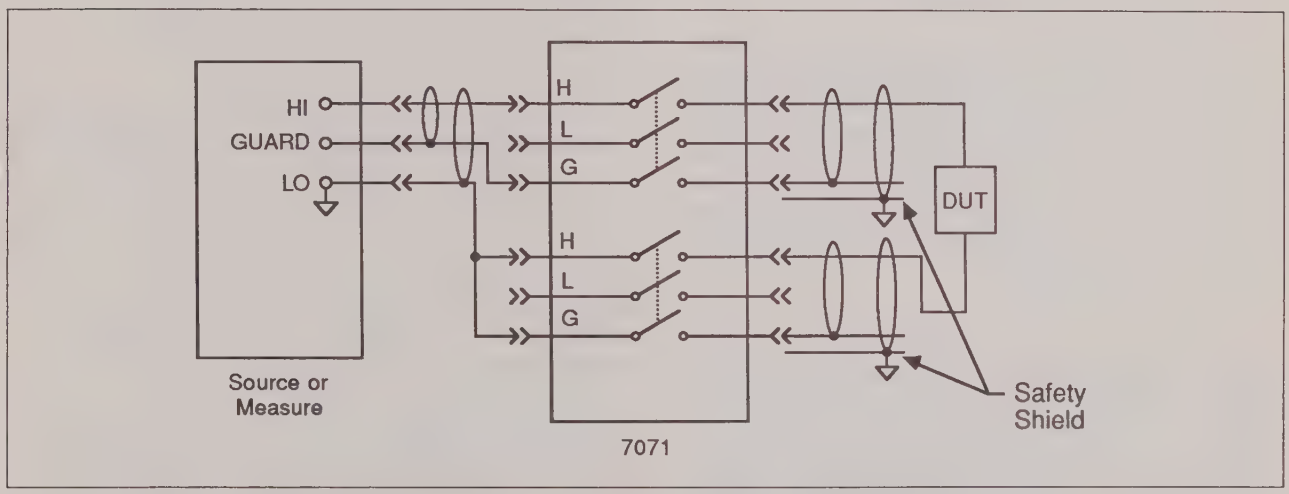


Figure 2-6. Driven Guard Example (Shielded)

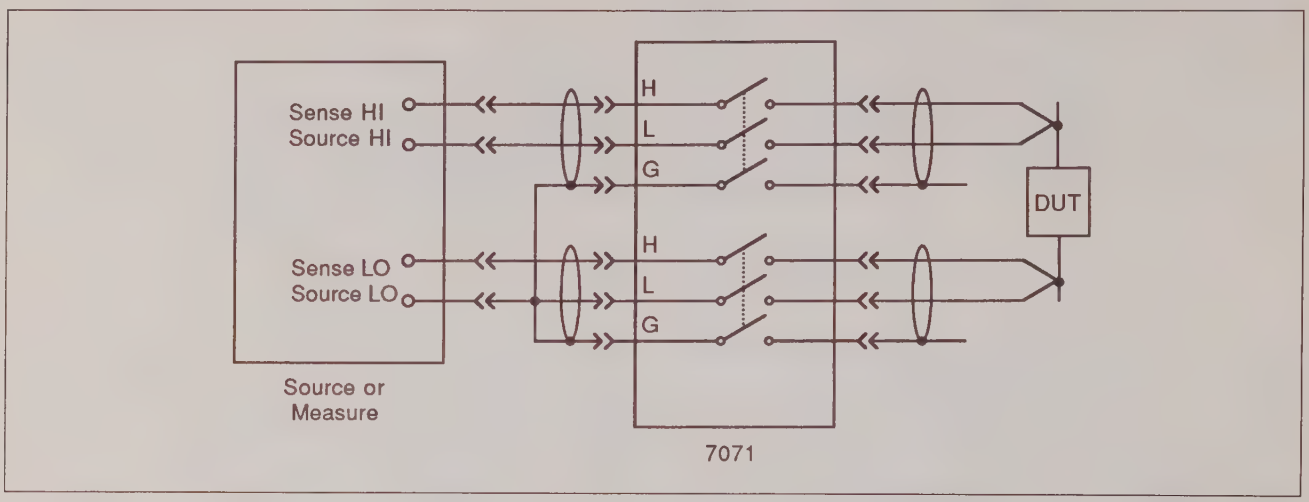


Figure 2-7. Sensing Example (Shielded)

2.5 CONNECTION METHODS

As shipped, all rows and columns of the 8 × 12 matrix are connected to the two "rack and panel" receptacles mounted on the rear panel of the matrix card. These receptacles will mate with either the optional mass terminated cable (Model 7078-MTC) or the plug provided in the optional connector kit (Model 7078-KIT). If the receptacles are not going to be used, they should be disconnected from the matrix. Connections are then made directly to quick-disconnect terminal blocks.

The following paragraphs explain the three connection methods. Keep in mind that based on convienence and performance considerations, it may best to use a combination of connection methods. For example, it may be most convienent to connect instrumentation to the matrix using quick-disconnect terminal blocks, while connecting DUT to the matrix using a mass terminated cable.

Some advantages of each of the connection methods are as follows:

Mass Terminated Cable Method (Model 7078-MTC)—Probably the most convenient method to make connections to the matrix card. By cutting the cable in half (or wherever appropriate), two separate cables, unterminated at one end, will result. These cables can then be hard wired to DUTs or to a user's test fixture. The plug on each cable will then connect to the ROWS or COLUMNS receptacle on the card. Using the whole cable (both plugs intact) makes it most convenient to connect the matrix card to a test fixture that uses a "rack and panel" receptacle.

Direct Connection Method—This method makes connections at the quick-disconnect terminal blocks bypassing the "rack and panel" receptacles. This method should be used when optimum guarding and/or shielding (i.e. high frequency noise) are required. If using the Model 7078-MTC cable, the concentric guard or shield conductor will be terminated at the receptacle. The direct connection method allows concentric guard and shield conductors to be extended to the terminal blocks. Another advantage of this method is that it is convenient to connect unterminated cables from instrumentation to the terminal blocks.

Connector Kit (Model 7078-KIT)—This kit contains a plug that mates to the "rack and panel" receptacles. This plug is used to custom build a mass terminated cable. Each conductor of the 20-foot Model 7078-MTC cable has 480mΩ of resistance. In an application where path resistance is critical, this path resistance may be too high. Thus, the main advantage of the connector kit is to build shorter, low resistance cables. An alternative to building a cable from scratch is to cut the Model 7078-MTC cable at a length that is suitable and then attach the plug to it.

WARNING

To avoid electrical shock which could result in injury or death, make sure all power is off and stored energy in external circuitry is discharged before making any connections to the matrix card.

CAUTION

Contamination will degrade the performance of the matrix card. To avoid contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card, and do not touch the board surfaces or components. On "rack and panel" connectors and quick disconnect terminal blocks, do not touch areas adjacent to the electrical contacts.

2.5.1 Connection Methods Using Mass Terminated Cable (Model 7078-MTC)

The Model 7078-MTC is a six meter (20 feet), 36 conductor cable terminated with a "rack and panel" plug on each end. This cable is used to connect the "COLUMNS" or "ROWS" receptacle on the rear panel of the card to external instrumentation and test circuits. Figure 2-8 shows how two cables can be used to connect rows and columns of the matrix card to external "rack and panel" receptacles. The external receptacles can then be hard wired to other connectors or wired directly to instrumentation and DUTs.

"Rack and panel" receptacle parts along with recommended installation tools are available from Keithley (see Table 2-2). Perform the following steps to wire a "rack and panel" receptacle.

1. Remove 1/8" of insulation from the wires that are to be connected to the receptacle.
2. Using the Model 7078-HCT crimping tool, connect a wire crimp tail to each of the wires.
3. Figure 2-9 provides contact identification for "ROWS" and "COLUMNS" receptacles. Using this illustration as a guide, insert the wire crimp tails into the receptacle. use the Model 7078 CIT insertion tool to push each wire crimp tail completely into the receptacle.

Another way to use the Model 7078-MTC cable is to remove one of the plugs. Cutting the cable in half will provide two 10 foot cables. Each cable can then be mated to the "ROWS" or "COLUMNS" receptacle (see Figure 2-10). The wire end of each cable can then be wired to another connector or wired directly to instrumentation or DUTs. The cable contains twelve bundles of wires each of which corresponds to a row or column. Each bundle contains three wires; a bare wire (guard) and two insulated wires that have a unique color combination for identification purposes. Table 2-3 provides the color combinations for each bundle. For example, with the cable connected to the "ROWS" receptacle of the matrix card, Row E can be identified by locating the bundle that has a red insulated wire (H) and a blue insulated wire (L). The bare wire in the bundle is guard (G).

The outer wrapping of each bundle is inslulated while the inner wrapping is conductive (guard). When the cable is cut, it is likely that the conductive side of the bundle wrapping will become exposed. Thus, each bundle, as well as each bare wire, should be insulated as follows:

1. Place a length of Teflon® tubing over each bare wire.
2. Place a length of shrink tubing over the bundle such that the frayed end of the bundle wrapping and part of the Teflon® tubing is covered.
3. Heat the shrink tubing.

Use the following procedure to connect the Model 7078 MTC cable to the matrix card:

1. Install the matrix card in the Model 707 mainframe as explained in paragraph 2.3.
2. Place the plug of the cable on the appropriate "rack and panel" receptacle such that the large diameter keying pin of the plug aligns with the large keyway of the receptacle (see Figure 2-11).
3. Using a slotted screwdriver, turn the locking screw clockwise until the plug is fully mated to the receptacle.

Table 2-2. Model 7071 Available Accessories

Model or Part	Description
Model 7078-CIT: Insertion and Extraction Tools	Used to install/remove wire crimp tails into/from "rack and panel" plugs and receptacles.
Model 7078-HCT: Hand Crimping Tool	Used to connect wire crimp tails to #18 to #26 gage wire.
Model 7078-KIT: Connection Kit	Contains one "rack and panel" plug, housing and 40 wire crimp tails.
Model 7078-MTC: Mass Terminated Cable	6 meter (20 ft.), 36 conductor cable terminated with "rack and panel" plugs. Mates to "rack and panel" receptacles.
CS-593: Receptacle	"Rack and panel" receptacle.
CS-426: Wire Crimp Tail	Contact for "rack and panel" plug or receptacle.
CS-570-3: Quick Disconnect Terminal Block	3-terminal block accomodates up to 16 AWG wires. Mates to matrix card board pin terminals.

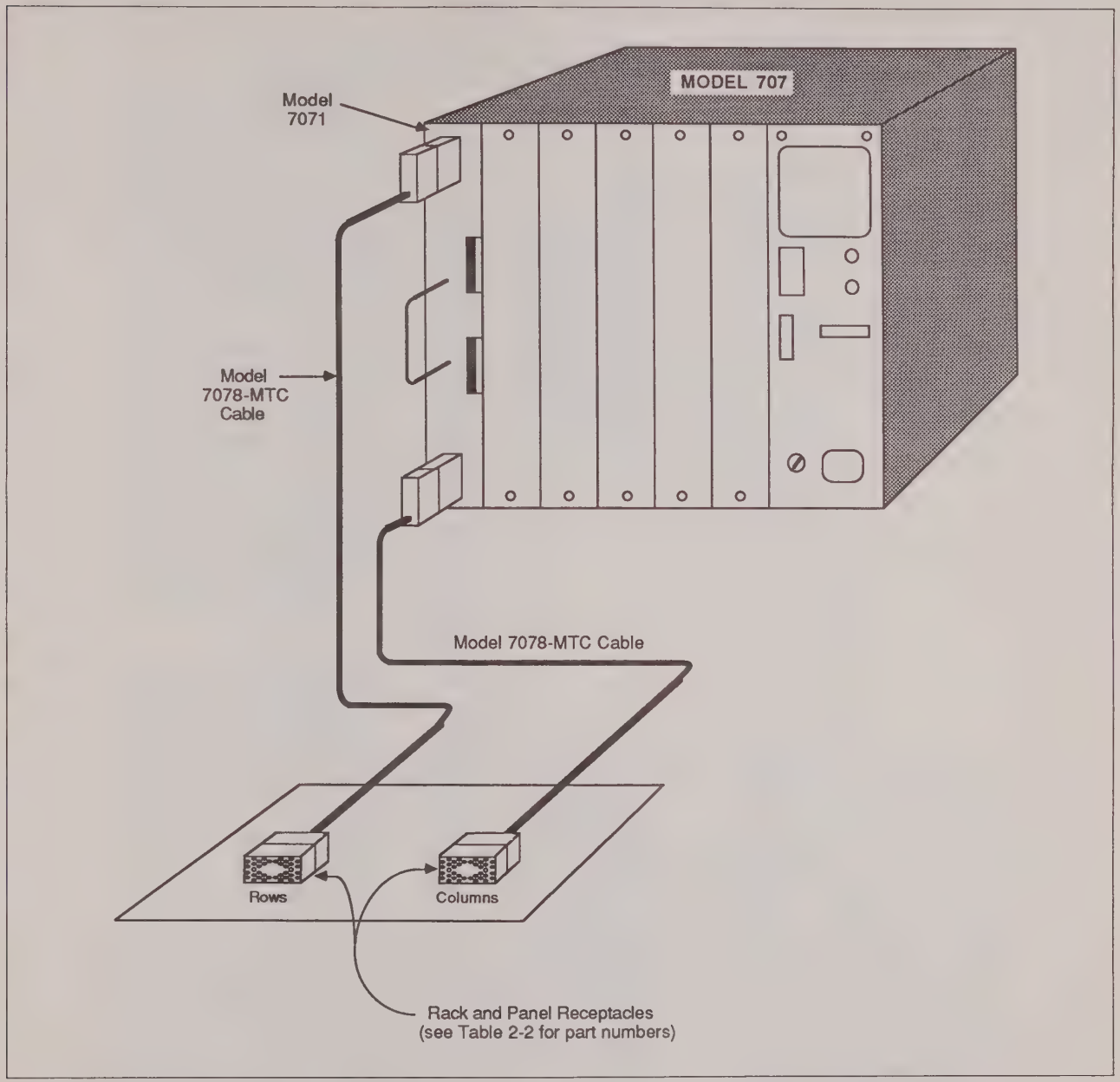
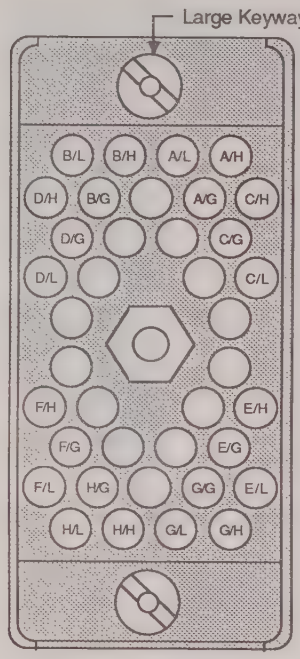


Figure 2-8. Connections Using two Model 7078-MTC Cables

Table 2-3. Model 7078 MTC Wire Identification

Wire Set	Terminal*	Insulation Color
COL 1 or ROW A	H	Brown
	L	Red
	G	Bare Wire
COL 2 or ROW B	H	Blue
	L	Black
	G	Bare Wire
COL 3 or ROW C	H	Red
	L	Yellow
	G	Bare Wire
COL 4	H	Green
	L	Black
	G	Bare Wire
COL 5 or ROW D	H	Black
	L	Red
	G	Bare Wire
COL 6	H	Red
	L	White
	G	Bare Wire
COL 7	H	Black
	L	Yellow
	G	Bare Wire
COL 8 or ROW E	H	Red
	L	Blue
	G	Bare Wire
COL 9	H	White
	L	Black
	G	Bare Wire
COL 10 or ROW F	H	Black
	L	Brown
	G	Bare Wire
COL 11 or ROW G	H	Green
	L	Red
	G	Bare Wire
COL 12 or ROW F	H	Orange
	L	Black
	G	Bare Wire

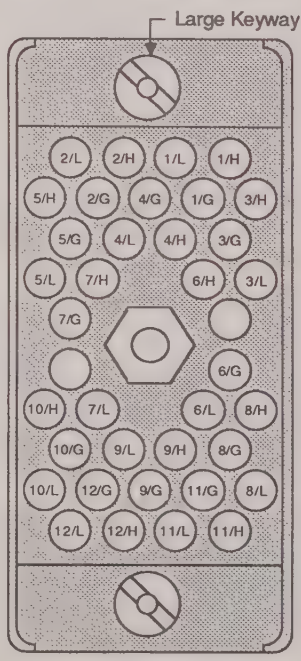
*H = High
L = Low
G = Guard



Row Receptacle

Contact	Row / Terminal
A/H	Row A/High Terminal
A/L	Row A/Low Terminal
A/G	Row A/Guard Terminal
B/H	Row B/High Terminal
B/L	Row B/Low Terminal
B/G	Row B/Guard Terminal
C/H	Row C/High Terminal
C/L	Row C/Low Terminal
C/G	Row C/Guard Terminal
D/H	Row D/High Terminal
D/L	Row D/Low Terminal
D/G	Row D/Guard Terminal

Contact	Row / Terminal
E/H	Row E/High Terminal
E/L	Row E/Low Terminal
E/G	Row E/Guard Terminal
F/H	Row F/High Terminal
F/L	Row F/Low Terminal
F/G	Row F/Guard Terminal
G/H	Row G/High Terminal
G/L	Row G/Low Terminal
G/G	Row G/Guard Terminal
H/H	Row H/High Terminal
H/L	Row H/Low Terminal
H/G	Row H/Guard Terminal



Column Receptacle

Contact	Column / Terminal
1/H	Column 1/High Terminal
1/L	Column 1/Low Terminal
1/G	Column 1/Guard Terminal
2/H	Column 2/High Terminal
2/L	Column 2/Low Terminal
2/G	Column 2/Guard Terminal
3/H	Column 3/High Terminal
3/L	Column 3/Low Terminal
3/G	Column 3/Guard Terminal
4/H	Column 4/High Terminal
4/L	Column 4/Low Terminal
4/G	Column 4/Guard Terminal
5/H	Column 5/High Terminal
5/L	Column 5/Low Terminal
5/G	Column 5/Guard Terminal
6/H	Column 6/High Terminal
6/L	Column 6/Low Terminal
6/G	Column 6/Guard Terminal

Contact	Column / Terminal
7/H	Column 7/High Terminal
7/L	Column 7/Low Terminal
7/G	Column 7/Guard Terminal
8/H	Column 8/High Terminal
8/L	Column 8/Low Terminal
8/G	Column 8/Guard Terminal
9/H	Column 9/High Terminal
9/L	Column 9/Low Terminal
9/G	Column 9/Guard Terminal
10/H	Column 10/High Terminal
10/L	Column 10/Low Terminal
10/G	Column 10/Guard Terminal
11/H	Column 11/High Terminal
11/L	Column 11/Low Terminal
11/G	Column 11/Guard Terminal
12/H	Column 12/High Terminal
12/L	Column 12/Low Terminal
12/G	Column 12/Guard Terminal

Note : Viewed from cable side of receptacle

Figure 2-9. Receptacle Contact Assignments

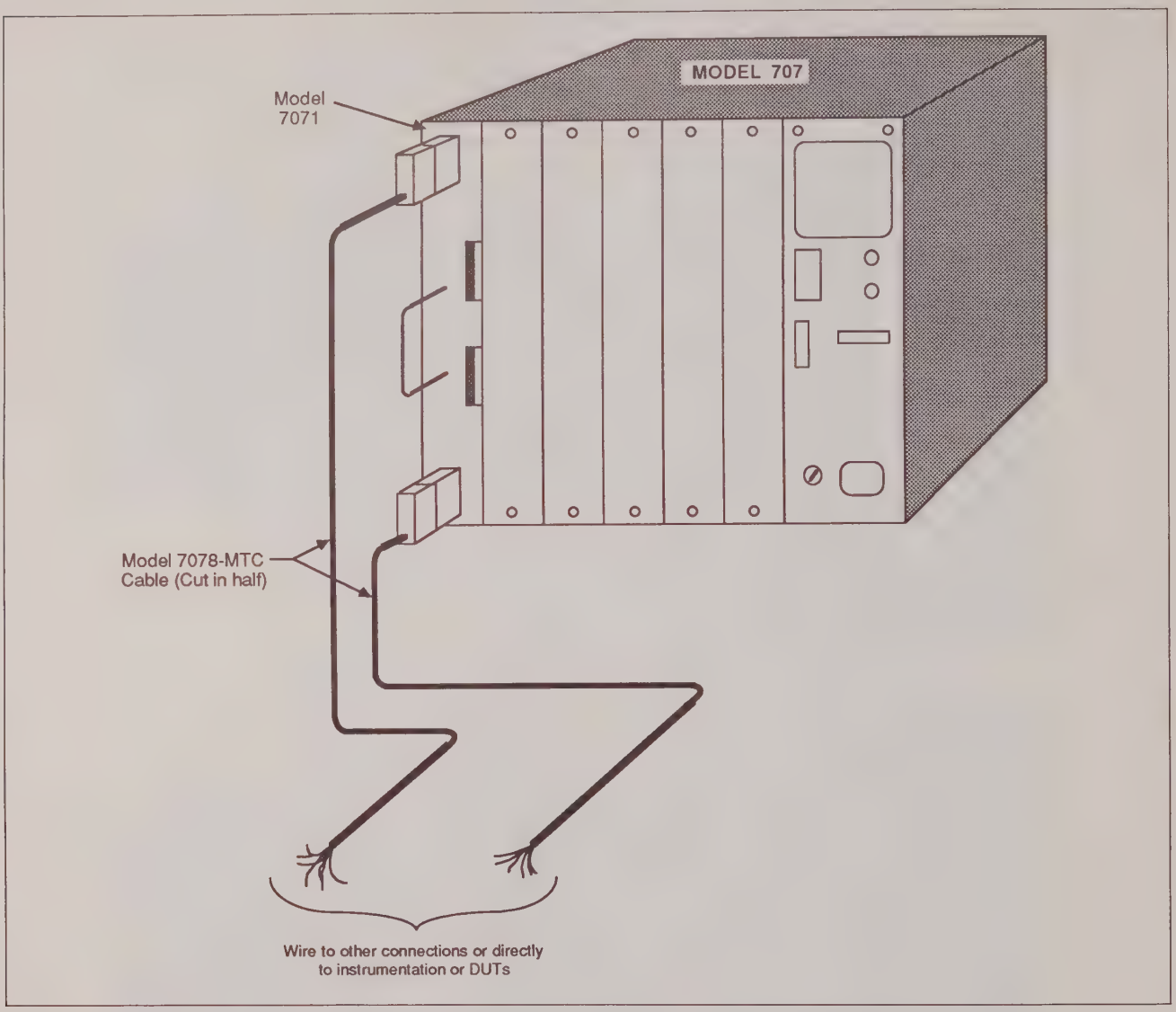


Figure 2-10. Connections Using One Model 7078-MTC Cable Cut in Half

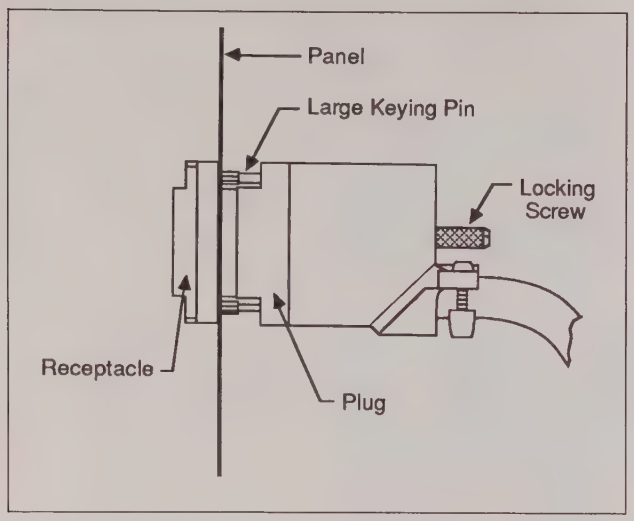


Figure 2-11. Connecting Plug to Receptacle

2.5.2 Direct Connection Method

With this method, connections are made directly to quick-disconnect terminal blocks. The "rack and panel" receptacles are not used. Additional terminal blocks are available from Keithley (see Table 2-2).

NOTE

For optimum performance, use a low noise, shielded cable that has excellent insulation qualitites such as Teflon® or polystyrene).

Perform the following steps to wire the matrix card:

1. Perform one of the following procedures (A or B):
   A. If leaving the terminal blocks connected to the receptacles, carefully pull the appropriate blocks off the matrix PC board. Tie wrap or tape the loose assemblies together and position them out of the way.
   B. If using the supplied terminal blocks, disconnect the receptacle wires from the ones you are going to use and carefully pull them off the PC board. Tie wrap or tape the loose receptacle wires together and position them out of the way.

NOTE

Receptacle wires are tagged for identification. Red wires are HI terminals, black wires are LO, and white wires are GUARD. Contact identification at the receptacles is provided in Figure 2-9.

2. Using a screwdriver, connect the circuitry to the terminal blocks. Figure 2-12 shows how a triaxial cable may be connected. The screw terminals accept up to #16 AWG wire.
3. The terminal blocks should be connected to the matrix card during installation of the card into the mainframe. The procedure to do this is contained in paragraph 2.3.

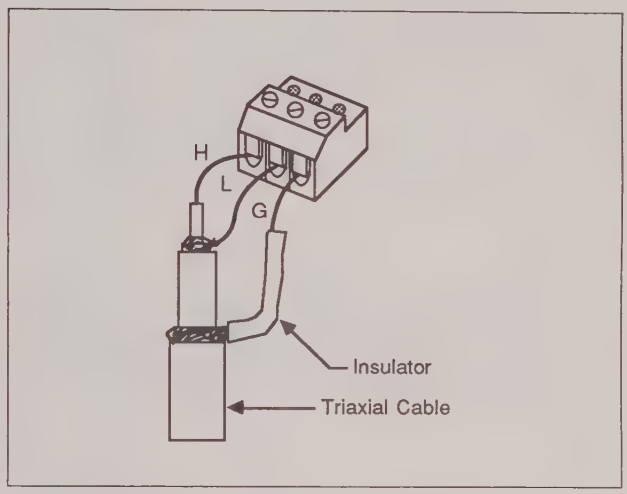


Figure 2-12. Terminal Block Connections

2.5.3 Connection Method Using Connector Kit (Model 7078-KIT)

The Model 7078-KIT contains the parts of one "rack and panel" plug. This kit allows the user to build a cable that will mate to the "rack and panel" receptacles of the matrix card.

NOTE

The following procedure shows how to properly connect a 36 conductor cable to a "rack and panel" plug. The cable used in the procedure is the same one used in the Model 7078-MTC and is available from Belden (P/N 9734). Modify the procedure accordingly if using a different cable or individual wires.

Perform the following steps to connect the 36 conductor Belden cable to the Model 7078-KIT plug:

1. Feed one end of the cable through the plug housing. Slide the housing far enough down the cable to set it out of the way.

NOTE

Refer to Figure 2-13 for steps 2 through 5.

2. Using a sharp knife, remove 1¾" of insulation from the end of the cable. Be careful not to cut into the insulated shield of any of the internal wire bundles.
3. Remove one inch of insulated shielding from each of the 12 bundles of wires.
4. Insulate the bare guard wire of each bundle so that they do not short out to each other. The insulation must be able to withstand a 200V potential.
5. Remove 1/8" of insulation from the 36 insulated wires.
6. Using the Model 7078-HCT crimping tool, connect a wire crimp tail to each of the 36 wires. The wires are 24 gage so be sure to use the slot labeled "22-26" on the tool.

NOTE

Figure 2-14 shows where the wires of each bundle belong. The wires in each bundle have a unique color combination that is different from the color combination of any other bundle.

7. Insulate the locking screws of the plug with shrink tubing as shown in Figure 2-15.
8. Orient the cable to the plug as shown in Figure 2-15, and using Figure 2-14 as a guide, insert the wire crimp tails into the plug. Use the Model 7078 CIT insertion tool to push each wire crimp tail completely into the plug.
9. Slide the housing over plug and install the four screws that secure the housing to the plug.
10. Tighten the two cable clamp screws on the housing.

The "rack and panel" plug will mate to either receptacle on the matrix card in the same manner as the Model 7078 MTC cable. The other end of the cable can be wired directly to instrumentation or DUTs, or to another connector.

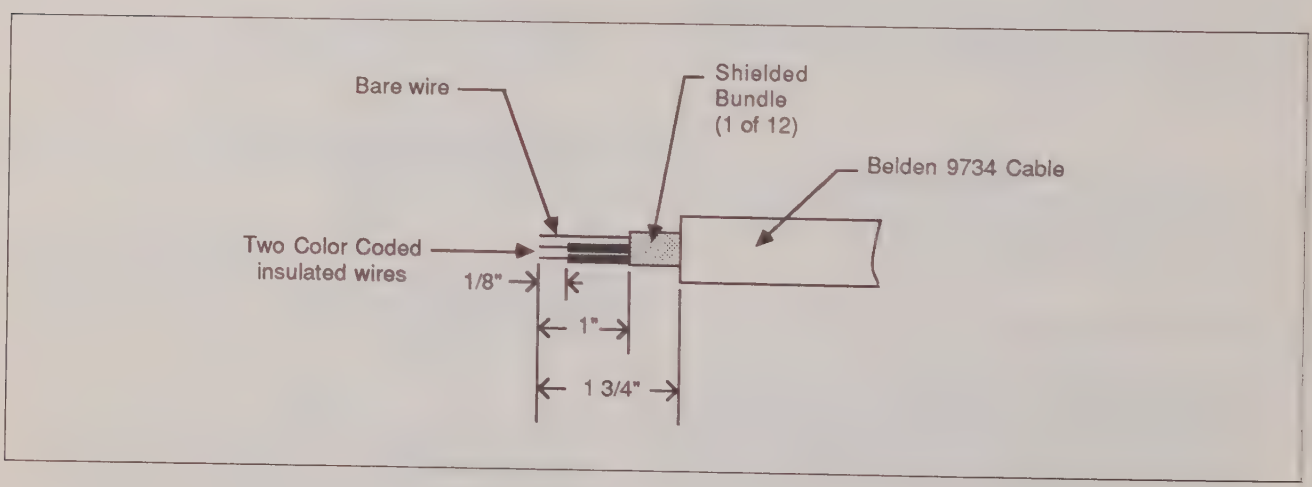


Figure 2-13. Cable Preparation

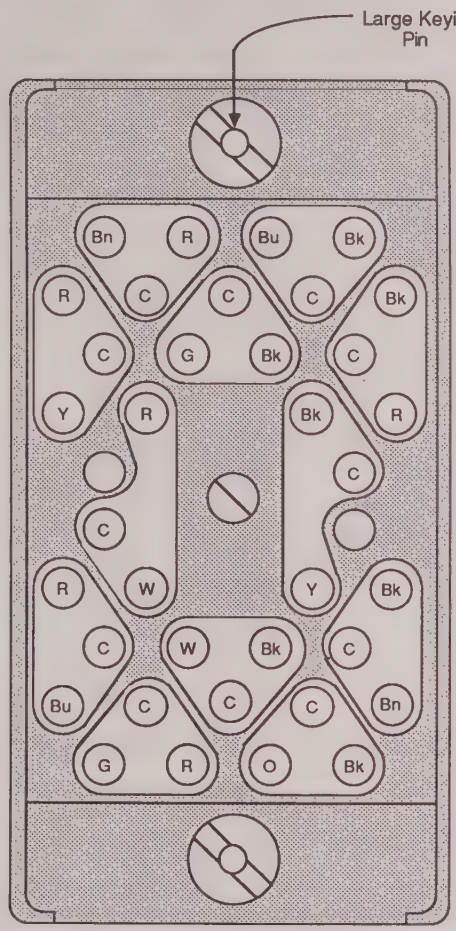


Figure 2-14. Connecting Beldon 9734 Cable to Receptacle

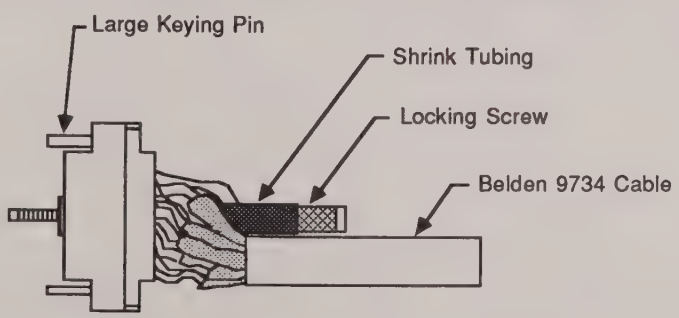


Figure 2-15. Cable Positions

2.6 MATRIX EXPANSION

With the use of additional Model 7071 matrix cards, larger matricies can be configured and are described in the following paragraphs.

NOTE

Some configurations require that the backplane row jumpers of the Model 707 be removed. The procedure to remove these jumpers can be found in the Model 707 Instruction Manual.

2.6.1 Narrow Matrix Expansion

As shipped from the factory, the rows of all six slots of the Model 707 are internally connected together. Thus, each card installed in the mainframe extends the matrix by 12 columns. For example, three cards installed in the Model 707 will result in an 8 × 36 matrix. Figure 2-16 shows three matrix cards installed in slots 1, 2 and 6.

Model 7071 matrix cards installed in slots 1, 2 and 3 of the Model 707 can be electrically isolated from slots 4, 5 and 6 by removing the backplane row jumpers. With the jumpers removed, the Model 707 can accomodate two complete, separate matricies using Model 7071 matrix cards (see Figure 2-17).

Table 2-4. Narrow Matrix Expansion*

Installed Matrix Cards	Resulting Matrix
1 Card	8 × 12
2 Cards	8 × 24
3 Cards	8 × 36
4 Cards	8 × 48
5 Cards	8 × 60
6 Cards	8 × 72

*Backplane row jumpers between slots 3 and 4 of mainframe must be installed for a matrix larger than 36 columns.

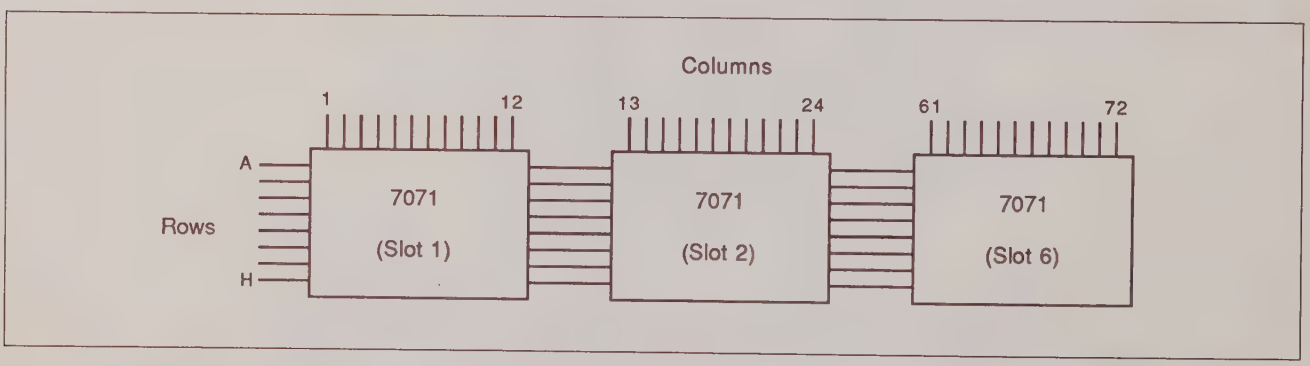


Figure 2-16. Narrow Matrix Example (8 × 36) (Backplane Jumpers Not Removed)

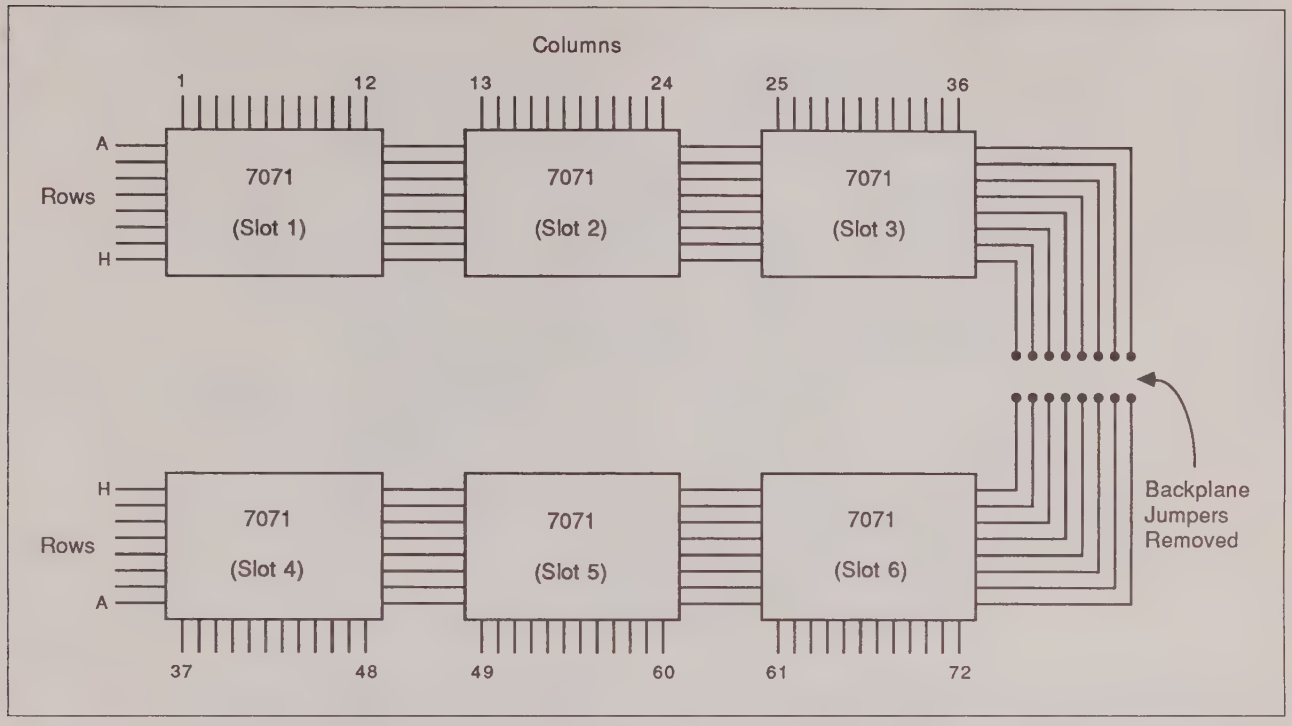


Figure 2-17. Two 8 × 36 Matrices Using Six Model 7071s

2.6.2 Wide Matrix Expansion

With the backplane row jumpers of the Model 707 removed, a wide matrix (16 rows) can be configured as shown in Figure 2-18. Columns of two cards can be connected together by using the Model 7071 MTC cable or by using individual wires from the "COLUMN" terminal blocks of one card to the "COLUMN" terminal blocks of another. Column connections to DUTs can be made at the "COLUMN" terminal blocks or at a "COLUMNS" receptacle (if not already used) using methods described in paragraph 2.5. Each screw terminal of the terminal blocks will accomodate an additional #22 AWG wire.

Table 2-5 summarizes the wide matrix possibilities per Model 707 mainframe.

Table 2-5. Wide Matrix Expansion*

Installed Matrix Cards	Card Locations in 707		Resulting Matrix
	Slots 1, 2 or 3	Slots 4, 5 or 6	
2 Cards	1 Card	1 Card	16 × 12
4 Cards	2 Cards	2 Cards	16 × 24
6 Cards	3 Cards	3 Cards	16 × 36

*Model 707 backplane row jumpers removed.

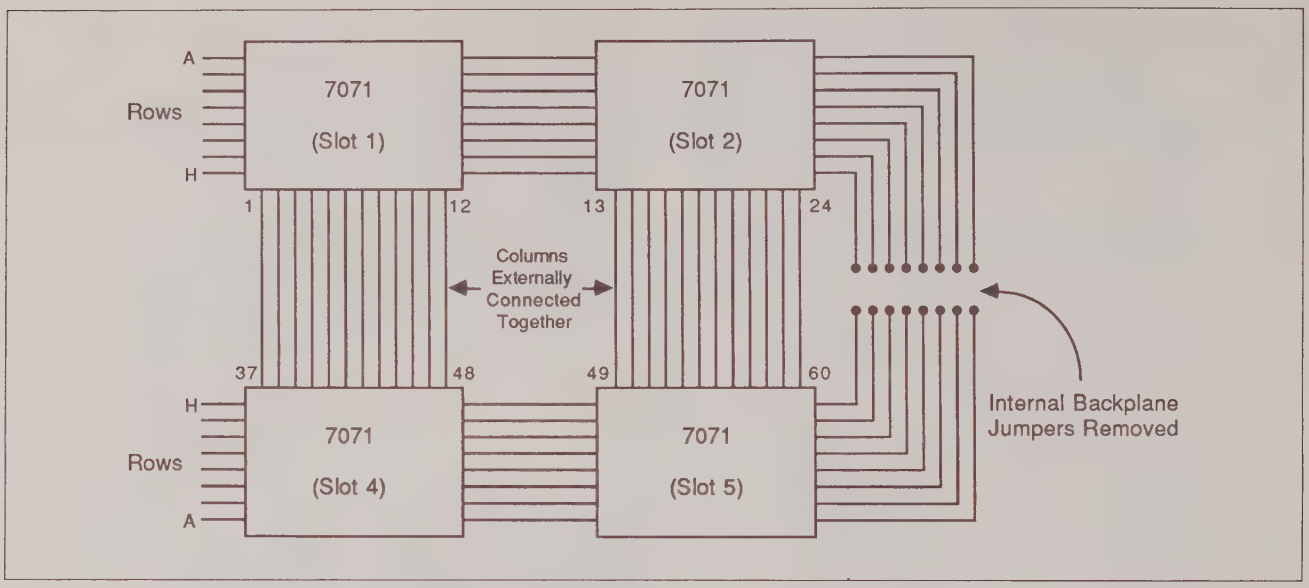


Figure 2-18. Wide Matrix Example (16 × 24)

2.6.3 Partial Matrix Implementation

A fully implemented matrix provides a relay at each potential crosspoint. For example, a fully implemented 16 × 24 matrix utilizing four Model 7071 matrix cards contains 384 crosspoints. A partially implemented matrix can be obtained by removing one Model 7071 from the mainframe (see Figure 2-19). The partial matrix is still 16 × 24, but contains only 288 crosspoints. An obvious advantage of a partial matrix is that fewer matrix cards are needed. Another reason to use a partial matrix is to keep certain devices from being connected directly to other certain devices. For example, a source in Figure 2-19 cannot be connected to DUT #2 with one "accidental" crosspoint closure. Three specific crosspoints must be closed in order to connect a source to DUT #2.

Methods to connect columns together and to external circuitry are explained in the previous paragraph.

2.6.4 Mainframe Matrix Expansion

Matricies using up to 30 Model 7071 matrix cards are possible by daisy-chaining five Model 707 mainframes together. Using 30 Model 7071 matrix cards provides 2880 crosspoints.

In general, connecting columns of a card in one mainframe to the columns of a card in another mainframe increases the the row numbers of the matrix. Connecting rows of any card in one mainframe to the rows of any other card in a second mainframe increases the column numbers of the matrix. See the Model 707 Instruction Manual for detailed information on daisy-chaining Model 707 mainframes.

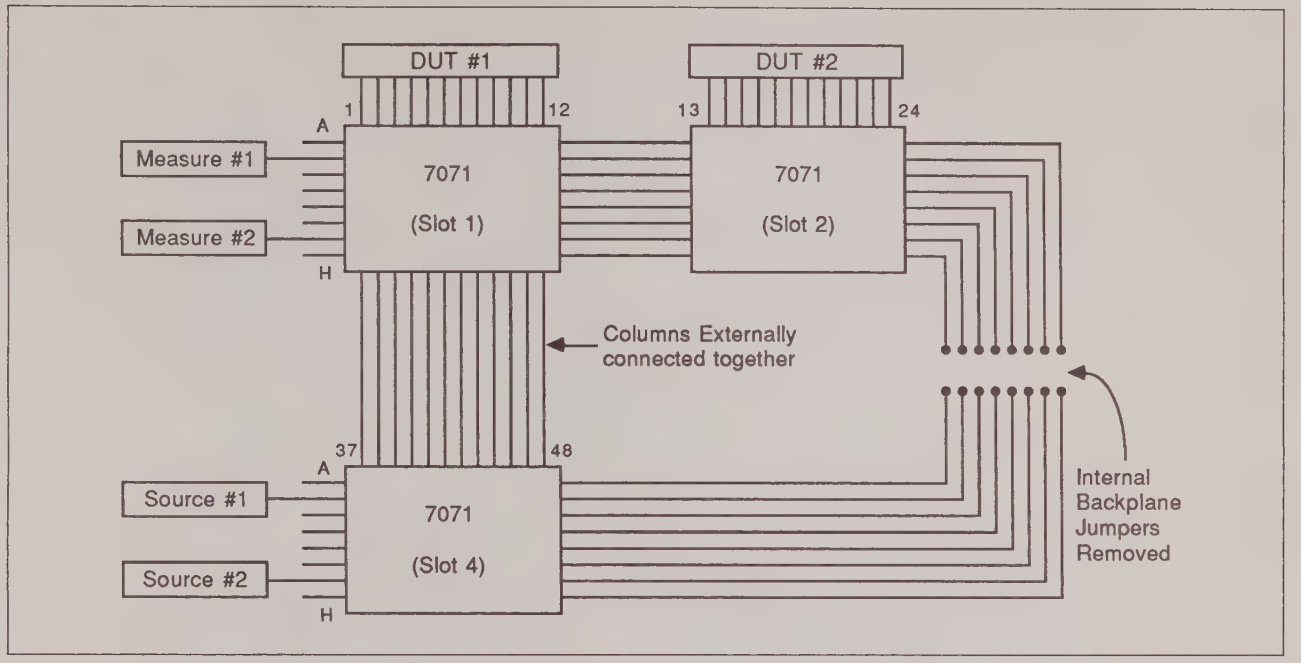


Figure 2-19. Partial Matrix Expansion (16 × 24)

2.7 TYPICAL CONNECTION SCHEMES

The information in this paragraph provides some typical connection schemes for single card, multiple card and multiple mainframe system configurations. All of the following examples show Model 7078-MTC cables cut in half. Keep in mind however, that in systems where path resistance is critical, cables should be kept as short as possible.

2.7.1 Single Card System

Figure 2-20 shows how external connections for a single card system might by made. Instrumentation is connected to matrix card rows. Using standard instrument cables that are unterminated at one end make it convenient to make connections at the quick-disconnect terminal blocks of the matrix card. Instrumention uses only four rows allowing the rest of the rows to be used by DUTs. A Model 7078-MTC cable cut in half, is then used to connect DUTs to matrix card columns and the remaining rows.

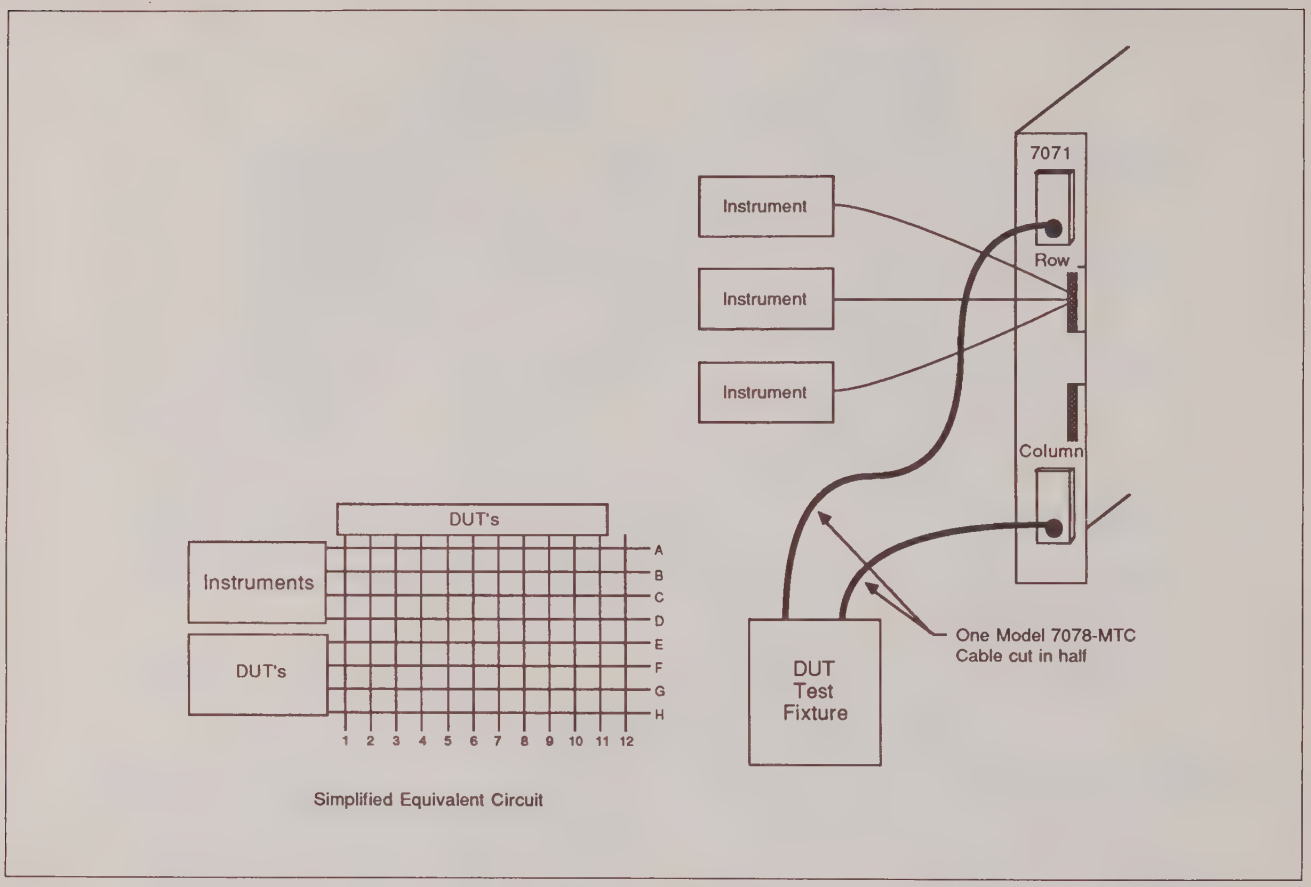


Figure 2-20. Single Card System Example

2.7.2 Multiple Card System

Figure 2-21 shows a system using four matrix cards. Again, instrumentation is connected to matrix card rows via the quick-disconnect terminal blocks. However, these connections could have been made using a Model 7078-MTC cable if desired. DUTs are connected to columns using two Model 7078-MTC cables cut in half.

2.7.3 Multiple Mainframe System

Figure 2-22 shows a system using eight matrix cards, requiring two Model 707s daisy-chained together. In this configuration all instrumentation and DUTs are connected to matrix card columns using four Model 7078-MTC cables cut in half. A single Model 7078-MTC cable is used to connect the rows of the master mainframe to the rows of the slave mainframe. Note that if path resistance is a critical factor, use a cable that is as short as possible. A Model 7078-MTC cable can be shortened or a custom cable can be built using two Model 7078-KIT connector kits.

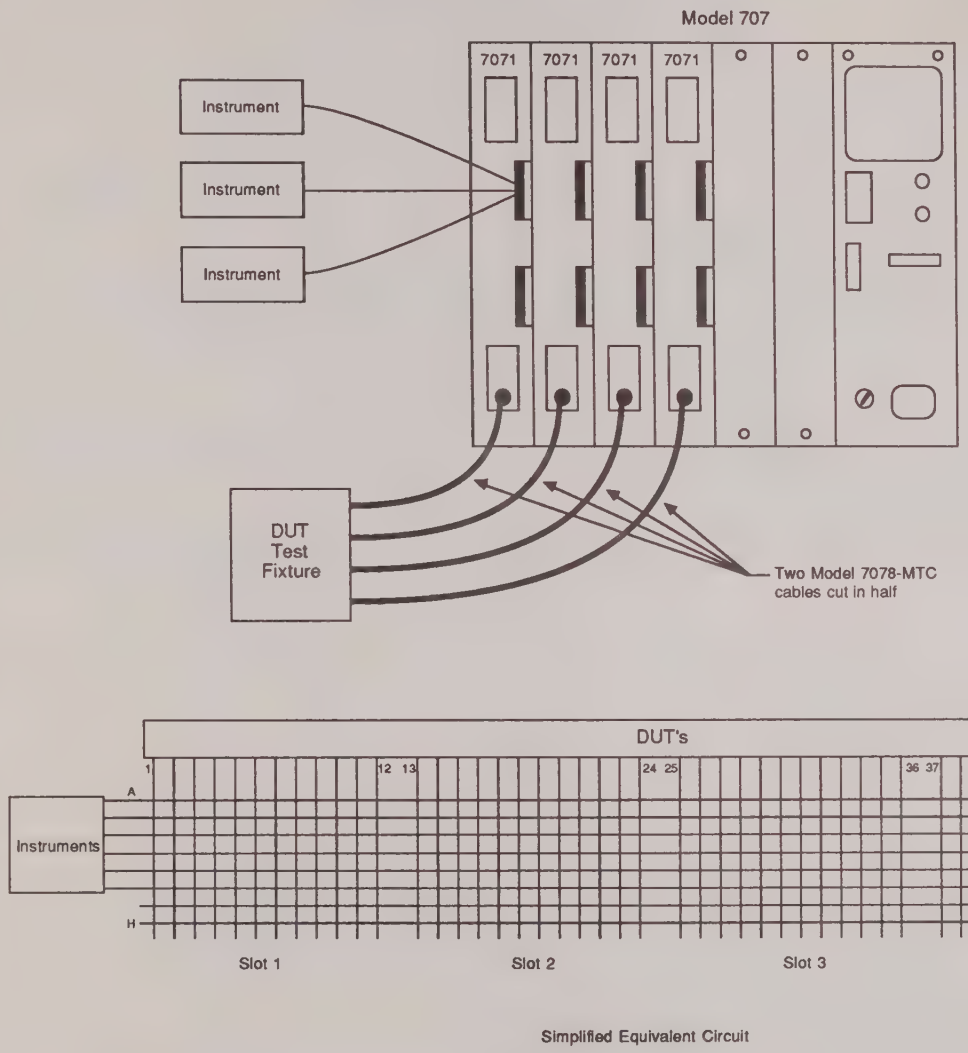


Figure 2-21. Multiple Card System Example

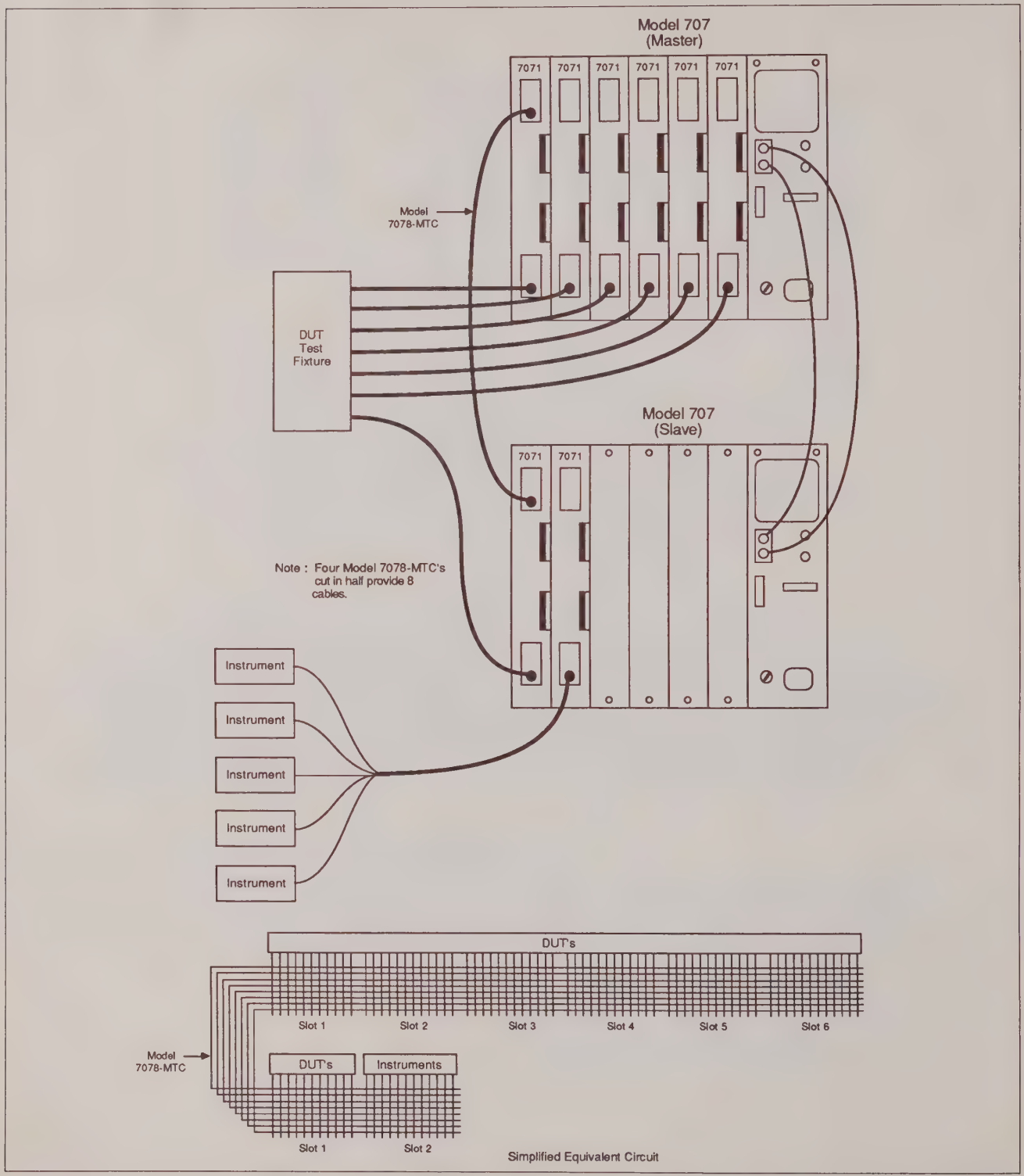


Figure 2-22. Multiple Mainframe Example

SECTION 3
Applications

3.1 INTRODUCTION

General applications to test thick film resistor networks and transistors are provided in this section. These applications are intended to demonstrate the versatility of using the matrix card in test systems.

3.2 THICK FILM RESISTOR NETWORK TESTING

A dedicated matrix system for testing thick film resistor networks is shown in Figure 3-1. This particular system provides three different methods to check thick films; four-wire resistance measurements, voltage measurements using an applied voltage, and voltage measurements using an applied current. In general, the method to use for testing is dictated by the intended application of the resistor network and the values of the resistors.

The system shown in Figure 3-1 tests three 3-element thick films, but can be expanded to test more by simply using additional Model 7071 matrix cards. The Model 707 will accomodate six matrix cards. Daisy-chaining five Model 707s expands the system to 30 matrix cards allowing 90 three-element thick films to be tested.

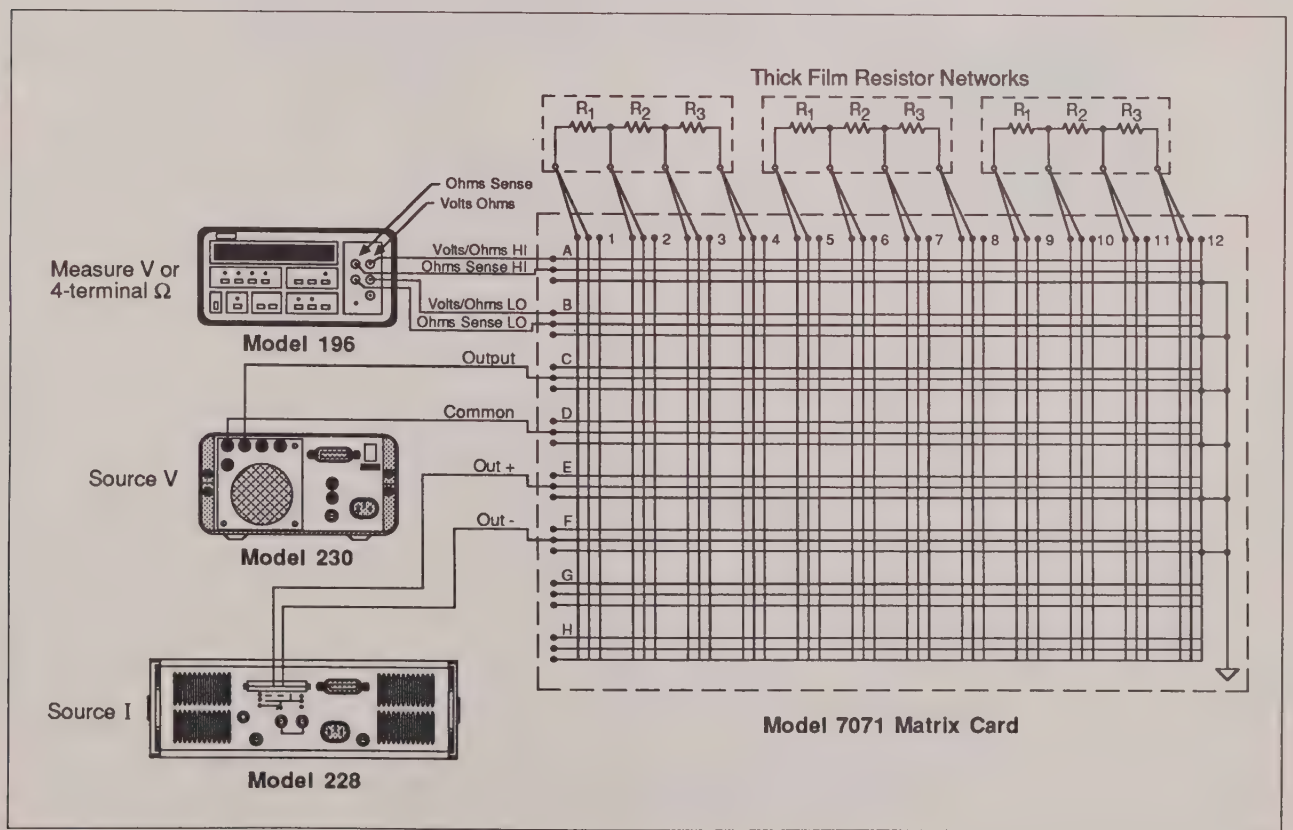


Figure 3-1. Thick Film Resistor Network Testing

3.2.1 Four-terminal Ohms Measurements

For general purpose testing, the Keithley Model 196 can be used to make 4-terminal resistance measurements of each thick film. As shown in Figure 3-2, OHMS HI and OHMS SENSE LO are connected to one matrix row, and OHMS LO and OHMS SENSE LO are connected to another matrix row. The third pole (G) of the matrix is not shown since it is not used. With this configuration, the resistance of each resistor element and/or combined elements can be measured by closing the appropriate crosspoints. In Figure 3-2, crosspoints A1 (row A, column 1) and B3 are closed to measure the combined resistance of R1 and R2.

The effects of thermal EMFs generated by relay contacts and connections can be cancelled by using the offset compensated ohms feature of the Model 196. To compensate for thermal EMFs, close two crosspoints (such as A1 and B1) that will short the input of the Model 196, enable ZERO to cancel internal offset, and then enable offset compensated ohms.

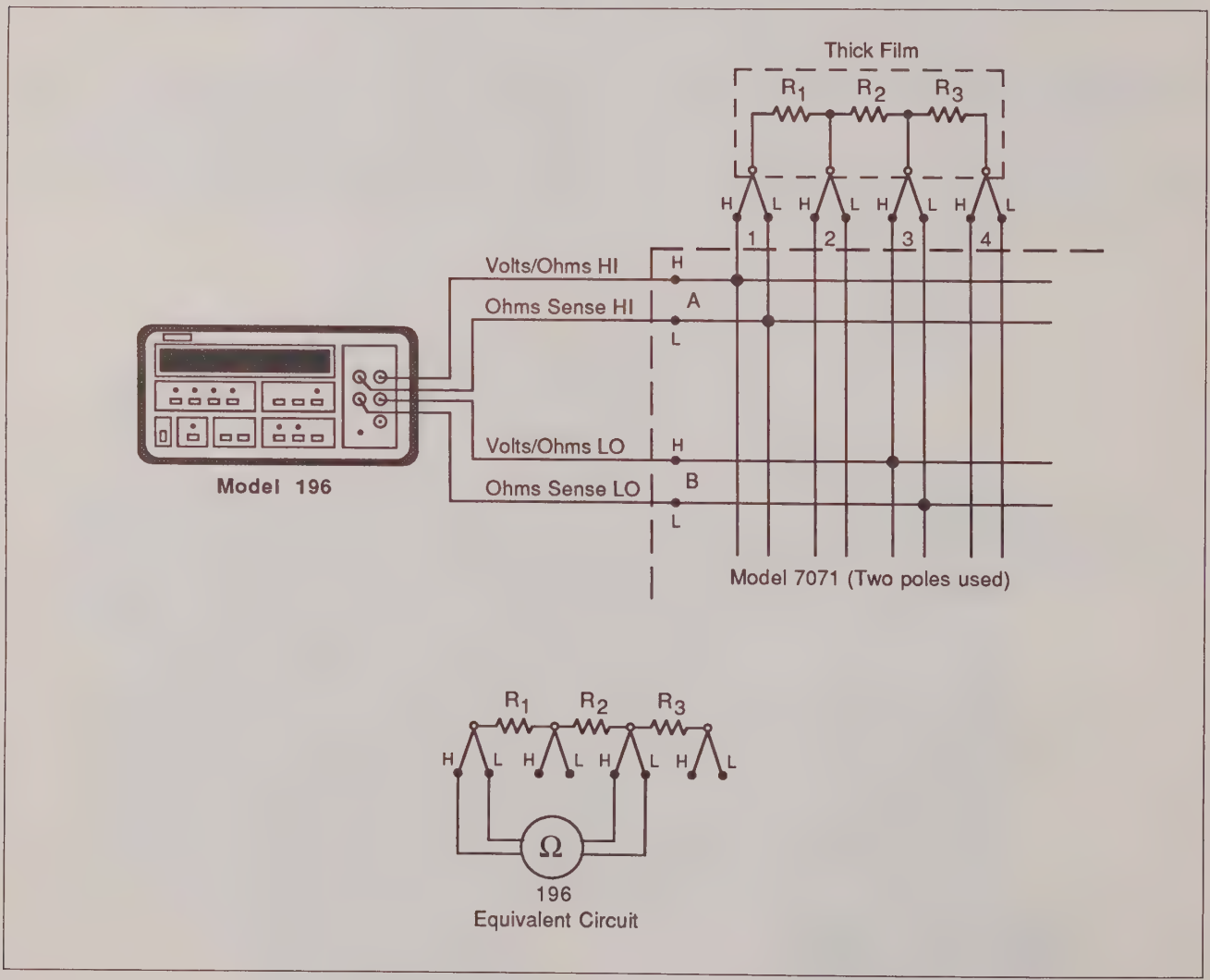


Figure 3-2. 4-Terminal Ohms Measurements

3.2.2 Voltage Divider Checks

For thick film resistor networks that are going to be used as voltage dividers, it may be desirable to test them using voltages that simulate actual operating conditions. This is a particularly useful test for resistor networks that have a voltage coefficient specification. The test system in Figure 3-1 uses a Keithley Model 230 to source voltage and the Model 196 to measure voltage.

A consideration in these checks is the affect of the Model 196 input impedance on voltage measurements. The input impedance is shunted across the resistor being measured. The resultant divider resistance is the parallel combination of the resistor under test and the input impedance. As long as the input impedance is much larger than the resistor being tested, the error introduced into the measurement will be minimal. Minimum input impedance requirements are, of course, determined by the accuracy needed in the measurement. The input impedances of the Model 196 are as follows: 300mV and 3V ranges, >1GΩ; 30V range, 11MΩ; 300V range, 10.1MΩ. For better input impedance requirements, the Keithley Model 617 Electrometer can be incorporated into the test system to measure voltage.

Another factor to be considered when checking low voltage dividers is thermal EMFs generated by the matrix card. A matrix card crosspoint can generate up to ±5μV of thermal EMF. Thus, when making low voltage measurements be sure to account for this additional error,

Even though four-terminal connections are made at the Model 196 and the resistor networks, the sense leads are internally disconnected from the input of the DMM when the volts function is selected. The simplified test system is shown in Figure 3-3.

The thick film is tested by applying a voltage across the resistor network and measuring the voltage across each resistor element and/or across combined elements. In Figure 3-3, crosspoints C1 and D4 are closed to apply voltage across the network, and crosspoints A3 and B4 are closed to measure the voltage drop across R3.

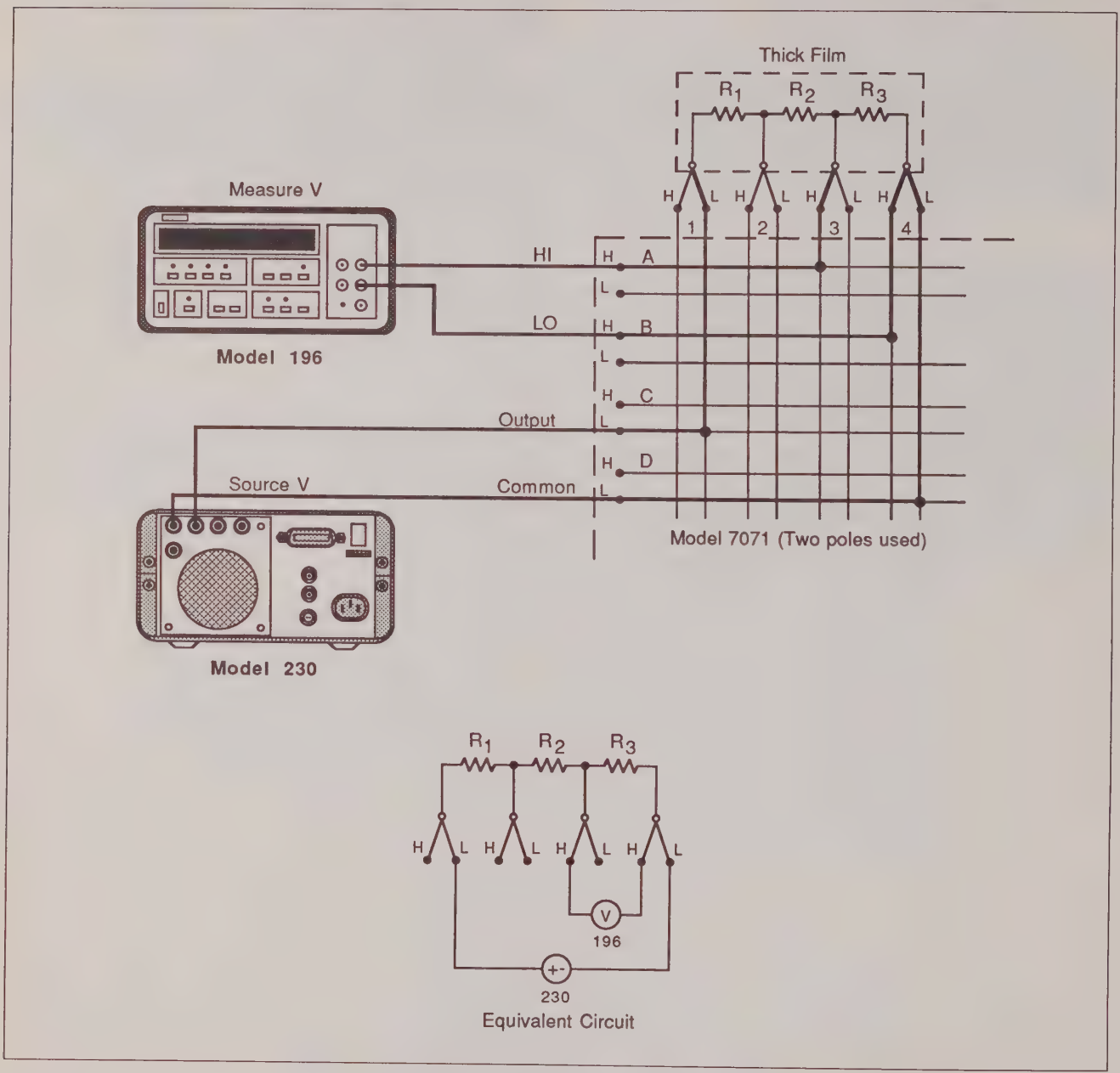


Figure 3-3. Voltage Divider Checks

3.2.3 Current Shunt Checks

As with voltage dividers, it may be desirable to test current shunt resistor networks under simulated operating conditions. The test system in Figure 3-1 uses a Keithley Model 228 to source current through the thick film resistor network and the Model 196 to measure voltage. As previously mentioned, the sense leads of the Model 196 are internally disconnected from its input in the volts function resulting with the simplfied test circuit shown in Figure 3-4.

CAUTION

To prevent damage not covered by the warranty, never source more than 1A to the matrix card and never switch more than 0.5A. To safely source more than 0.5A (but less than 1A), first set the current source to output zero and then close and/or open the appropriate crosspoints. This is called "cold" switching.

The thick film is tested by sourcing a current through the current shunt network and measuring the voltage drop across each resistor element and/or across combined resistor elements. In Figure 3-4, crosspoints E1 and F4 are closed to source current through the shunt, and crosspoints A1 and B2 are closed to measure the voltage drop across R1.

3.3 TRANSISTOR TESTING

A matrix system for testing DC parameters of transistors is shown in Figure 3-5. This system uses a current source (Keithley Model 224), a voltage source (Keithley Model 230) and a DMM (Keithley Model 196) to measure current and/or voltage. This system tests three transistors, but can be expanded to test more by simply using additional Model 7071 matrix cards. The Model 707 will accomodate six matrix cards. Daisy-chaining five Model 707s expands the system to 30 matrix cards allowing 90 transistors to be tested.

NOTE

To check FETs, or transistors that have high gain or low power, equipment that has lower offset current and higher impedance must be used. To check these devices, the Keithley Model 7072 Semiconductor Matrix Card and the Keithley Model 617 Electrometer can be used.

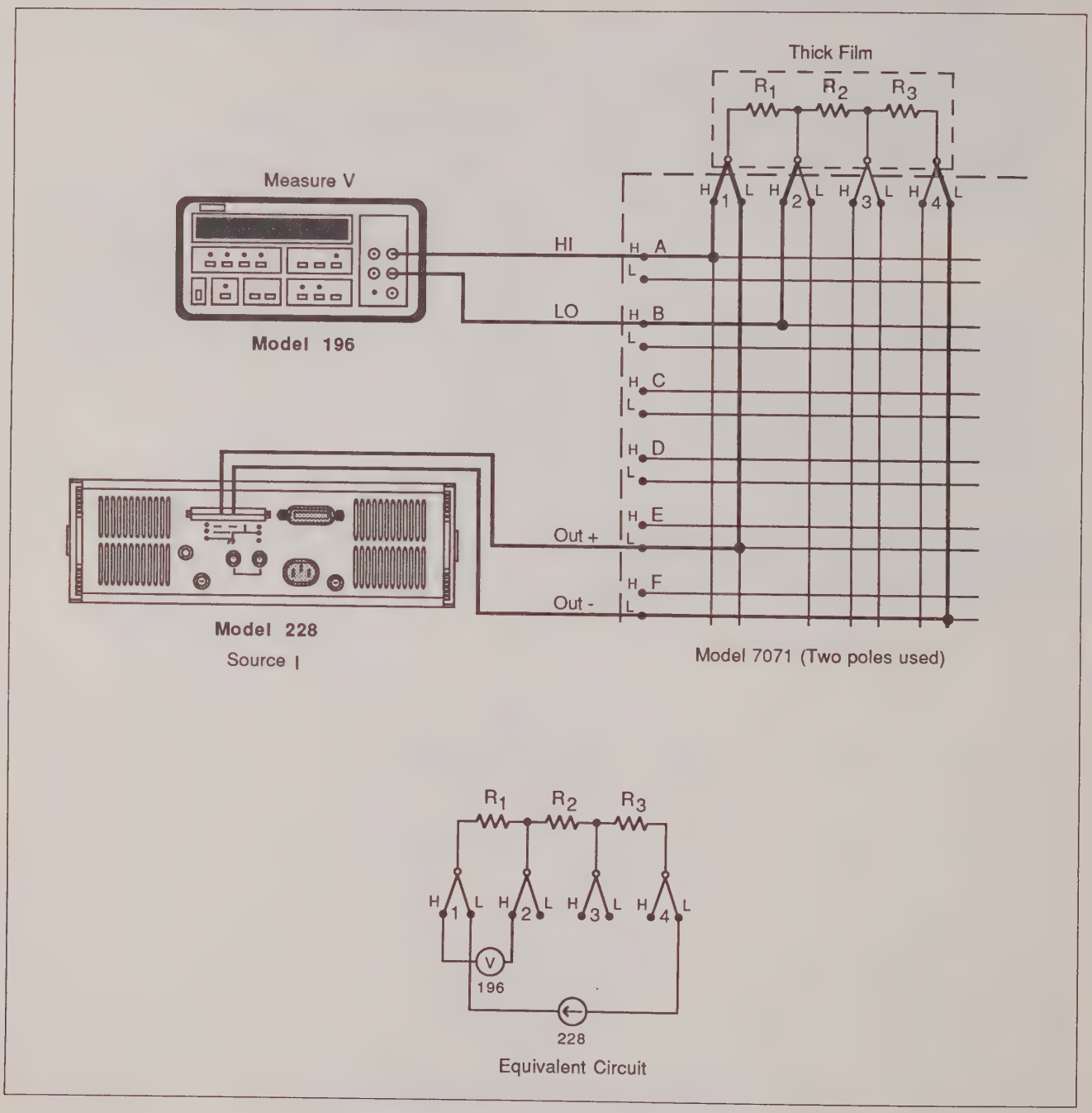


Figure 3-4. Current Shunt Checks

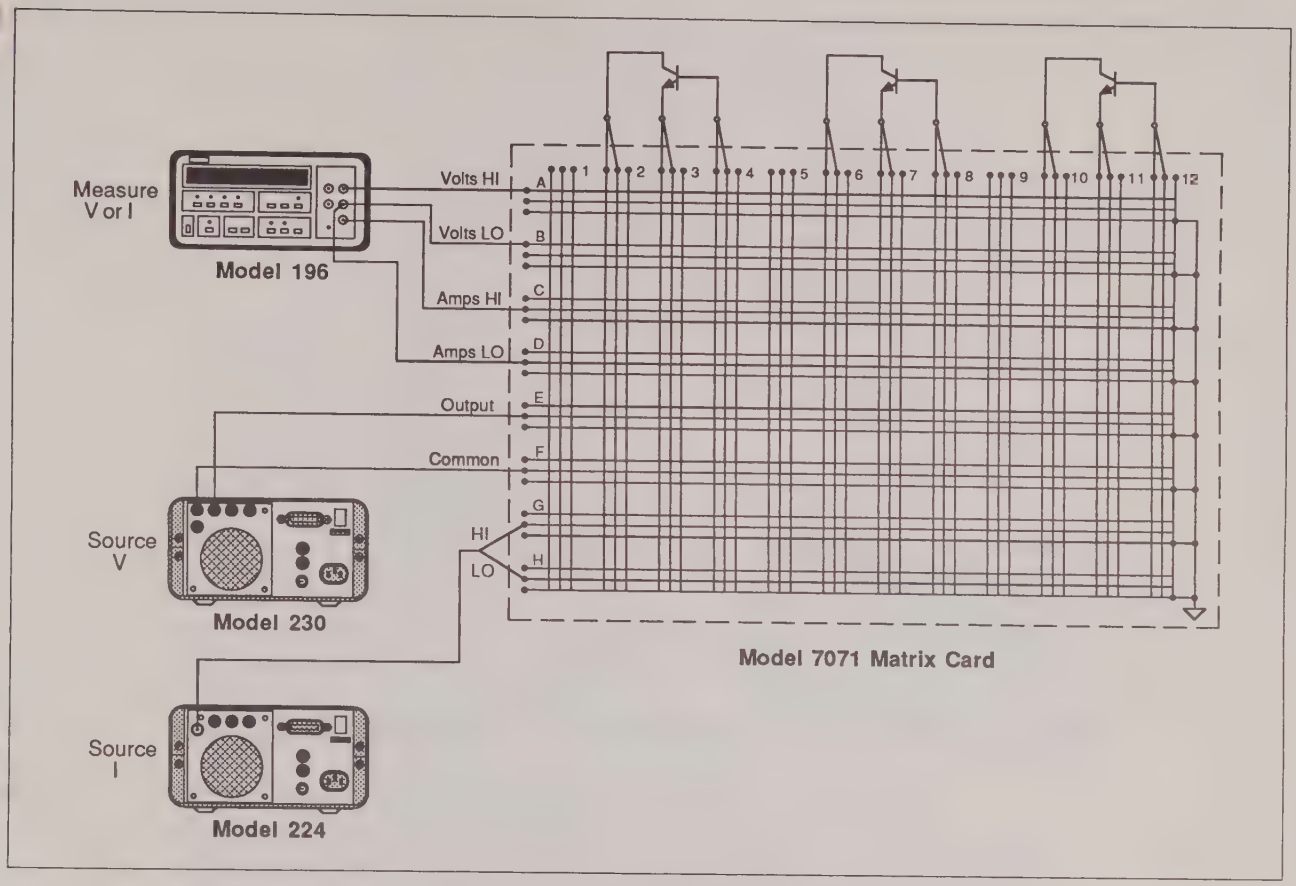


Figure 3-5. Transistor Testing

3.3.1 Current Gain Checks

The DC current gain of a general purpose transistor can be checked by configuring the transistor as a common-emitter amplifier. Figure 3-6 shows which crosspoints to close to configure the amplifier circuit. In this circuit, gain is calculated by dividing collector current (measured by the Model 196) by base current (sourced by the Model 224). A profile of the transistor operating characteristics can be obtained by measuring the collector current over a specified voltage range (V_{CE}) for different base bias currents. For example, Figure 3-7 shows the characteristics of a typical NPN silicon transistor at base bias currents (IB) of 20μA, 40μA, 60μA and 80μA.

3.3.2 I_E and V_{BE} Measurements

The versitility of using a matrix is demonstrated in Figures 3-8 and 3-9. The transistor is still configured as a common-emitter amplifier, but the Model 196 is removed from the collector circuit and used to measure emitter current and base-to-emitter voltage. Notice that external connection changes are not required. All connection changes are accomplished by control of matrix crosspoints.

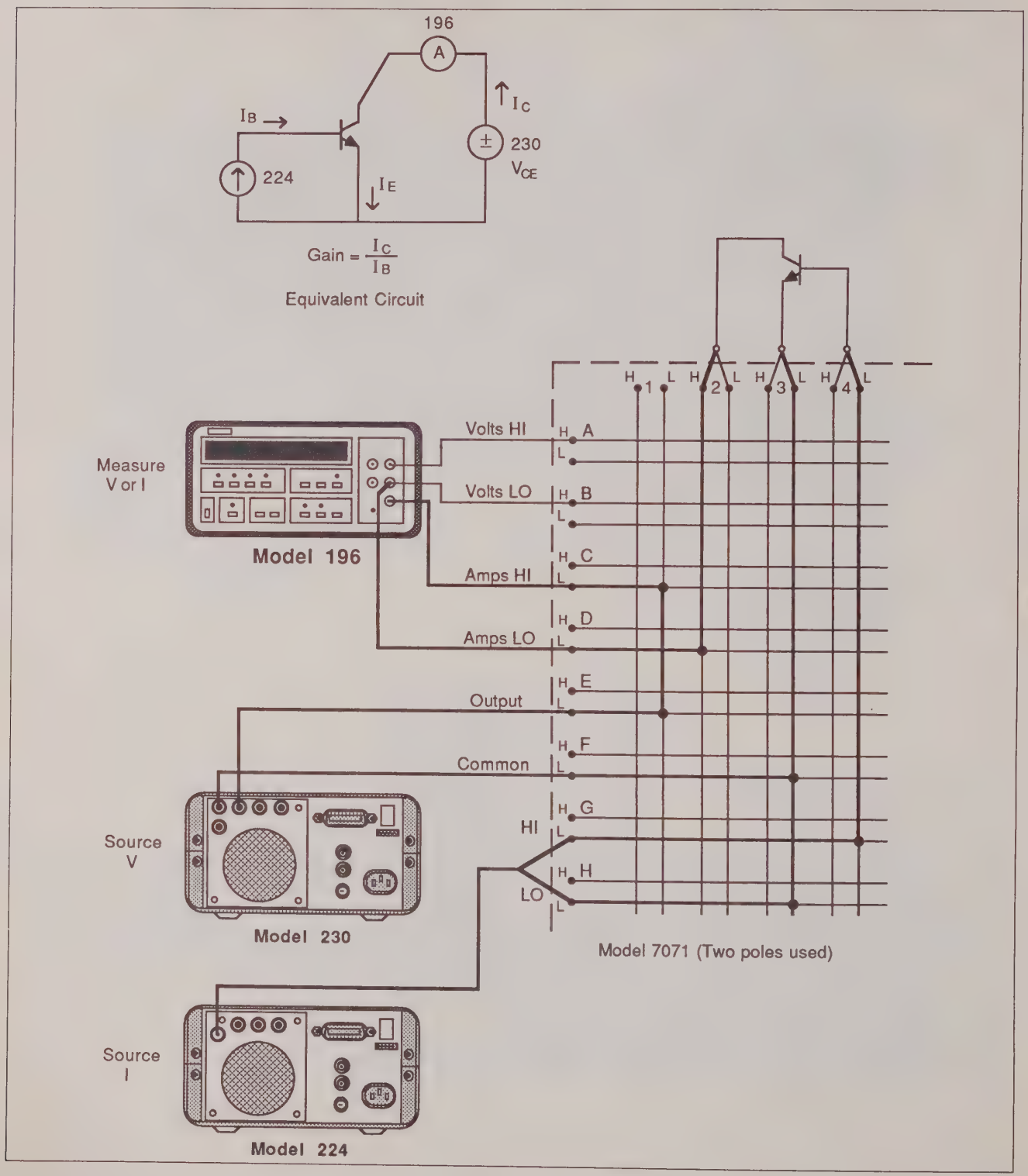


Figure 3-6. Transistor Current Gain Checks

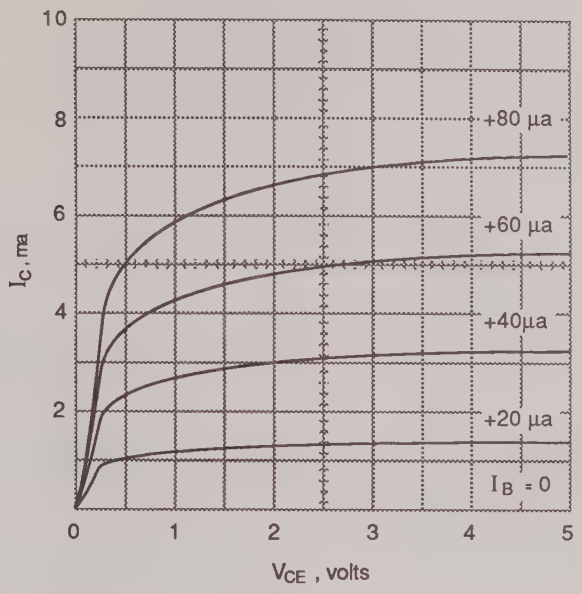


Figure 3-7. Common-Emitter Characteristics of an NPN Silicon Transistor

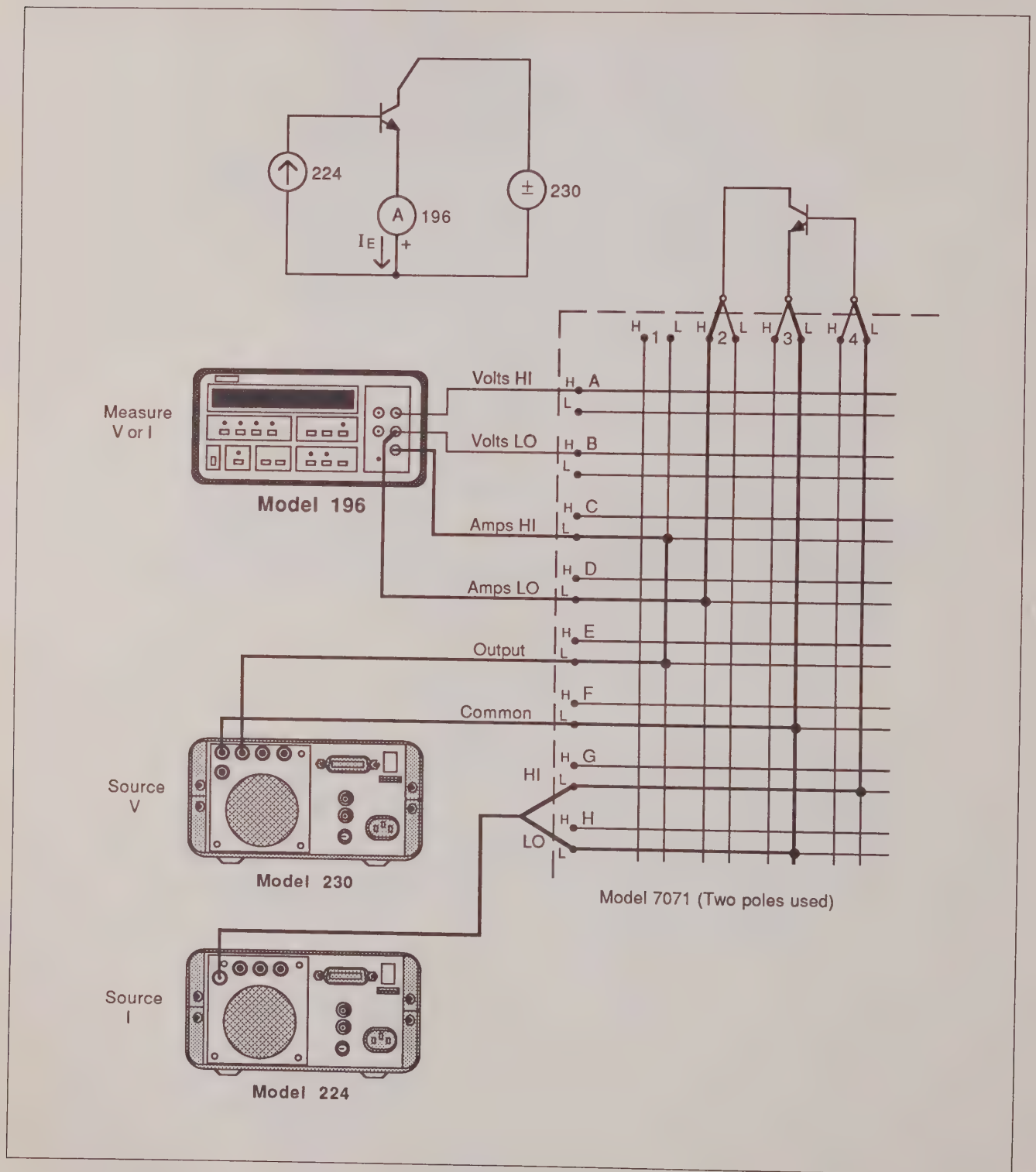


Figure 3-8. Transistor V_{BE} and I_E Measurements

SECTION 4
Service Information

4.1 INTRODUCTION

This section contains information necessary to service the Model 7071 General Purpose Matrix Card and is arranged as follows:

4.2 **Handling and Cleaning Precautions:** Discusses handling procedures and cleaning methods for the matrix card.

4.3 **Relay Test Program:** Explains how to connect the matrix card to the Model 707 mainframe for the relay test program.

4.4 **Performance Verification:** Covers the procedures necessary to determine if the card is operating properly.

4.5 **Principles of Operation:** Briefly discusses circuit operation.

4.6 **Special Handling of Static-Sensitive Devices:** Reviews precautions necessary when handling static-sensitive devices.

4.7 **Troubleshooting:** Presents some troubleshooting tips for the matrix card.

4.2 HANDLING AND CLEANING PRECAUTIONS

Because of the high impedance circuits on the Model 7071, care should be taken when handling or servicing the card to prevent possible contamination, which could degrade performance. The following precautions should be taken when handling the matrix card.

1. Do not store or operate the card in an environment where dust could settle on the circuit board. Use dry nitrogen gas to clean dust off the card if necessary.
2. Handle the card only by the handle and side edges. Do not touch any board surfaces, components, or edge connectors. Do not touch areas adjacent to electrical contacts. When servicing the card, wear clean, white cotton gloves.
3. If making solder repairs on the circuit board, use a flux that is rosin RMA based. Remove the flux from these areas when the repair is complete. Use Freon® TMS or TE, or the equivalent along with plenty of clean cotton swabs to remove the flux. Take care not to spread the flux to other areas of the circuit board. Once the flux has been removed, swab only the repaired area with methanol, then blow dry the board with dry nitrogen gas.
4. After cleaning, the card should be placed in a 50°C low humidity environment for several hours.

4.3 RELAY TEST PROGRAM SETUP

The Model 707 comes equipped with a test program on disk that will test all relays of Model 7071s installed in the mainframe. The test program will flag any relay that fails to close when energized or open when de-energized. Instructions for using the test program with an IBM PC or XT, or HP 200 or 300 series computer are contained in the Model 707 Instruction Manual.

Perform the following steps to configure the Model 7071 for relay testing:

1. Remove the relay test terminal block from the rear panel of the Model 707. This is a quick-disconnect terminal block and simply pulls off the rear panel terminal strip.
2. Connect the relay test terminal block to rows A and B of any Model 7071 card installed in the mainframe as shown in Figure 4-1. Note that terminals 5 and 6 of the relay test terminal block must be shorted together. Terminals H, L and G of row B of the Model 7071 must also be shorted together.
3. Re-install the relay test terminal block into the rear panel of the Model 707 mainframe and refer to the Model 707 Instruction Manual to run the test program.

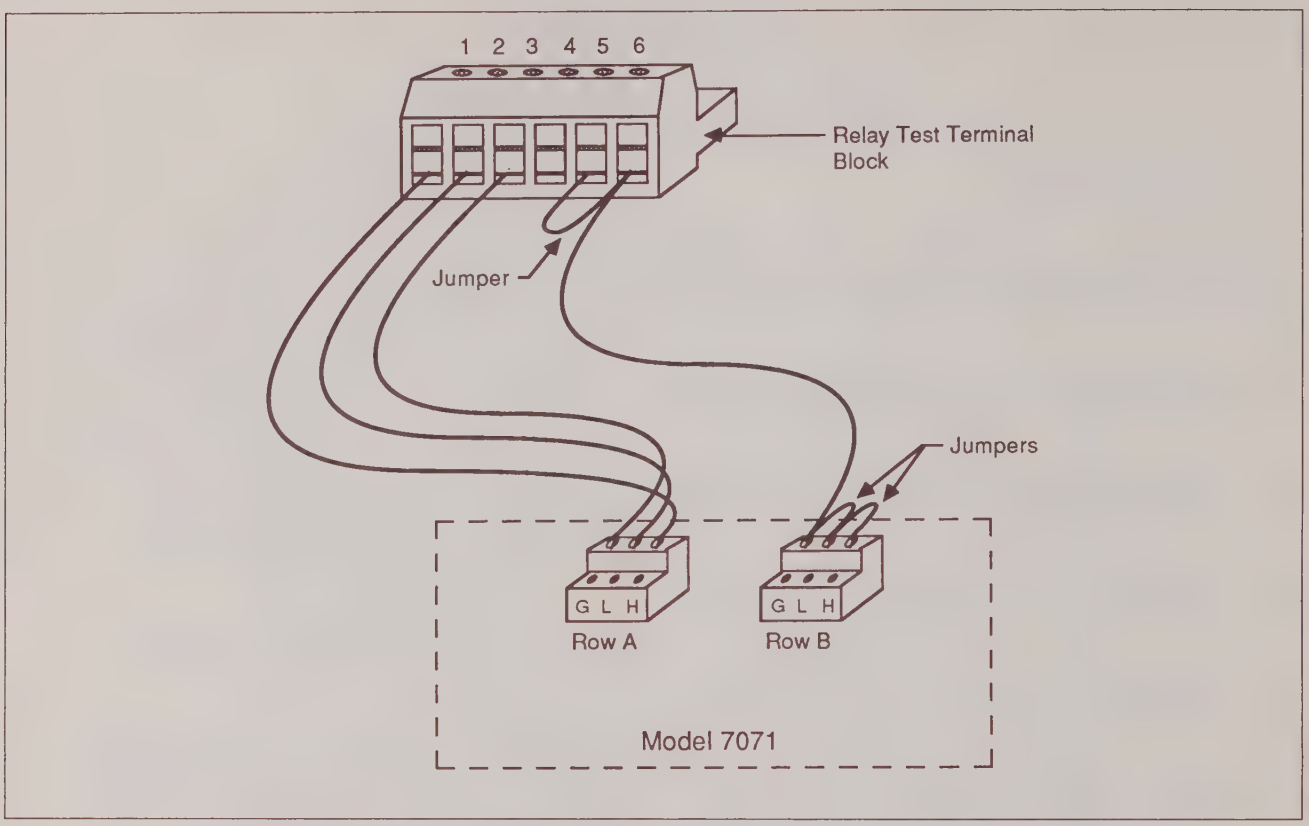


Figure 4-1. Relay Test Setup

4.4 PERFORMANCE VERIFICATION

The following paragraphs discuss performance verification procedures for the Model 7071, including path resistance, offset current, contact potential, and isolation.

The procedures in this section are rather lengthy due to the large number of row and column combinations that are checked. As an alternative to this extensive testing, it may be desirable to check only those paths that are going to be used, or those that are suspected of being faulty.

The procedures in this section make external equipment connections at the terminal strip on the PC board. If using the "rack and panel" receptacles of the matrix card to make connections, modify the procedures accordingly. Connection techniques to "rack and panel" receptacles are covered in Section 2.

The performance verification procedures must be performed with only one matrix card (the one being checked) installed in the Model 707 mainframe. Also, the Model 707 must not be daisy-chained to another Model 707.

CAUTION

Contamination will degrade the performance of the matrix card. To avoid contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card, and do not touch the board surfaces or components. On "rack and panel" connectors and quick disconnect terminal blocks, do not touch areas adjacent to the electrical contacts.

NOTE

Failure of any performance verification test may indicate that the matrix card is contaminated. See paragraph 4.2 to clean the card. If the test still fails after cleaning, then try cleaning the backplane (see the Model 707 Instruction Manual).

4.4.1 Environmental Conditions

All verification measurements should be made at an ambient temperature between 18° and 28°C, and at a relative humidity of less than 70%.

4.4.2 Recommended Equipment

Table 4-1 summarizes the equipment necessary for performance verification, along with the application for each unit.

NOTE

Do not use the Model 7070 Universal Adapter Card as an extender card to verify performance of the Model 7071. The Model 7071 must be installed in the Model 707 mainframe.

4.4.3 Path Resistance Tests

Perform the following steps to verify that each contact of every relay is closing properly and that the resistance is within specification.

NOTE

Refer to Figure 4-2 for the following procedure.

1. Turn the Model 707 off if it is on.
2. Using bare jumper wires, connect all terminals of the matrix columns together to form one common terminal. Each screw terminal of the quick-disconnect terminal blocks will accomodate two #22 AWG wires. Keep the jumper wires as short as possible.
3. Remove the eight "ROWS" quick-disconnect terminal blocks from the PC board of the matrix card. This allows test lead connections to be made at the PC board terminal posts.
4. Place the Model 7071 in slot 1 of the Model 707, but do not push it all the way into the mainframe.
5. Set the Model 196 to the 300Ω range and connect four test leads to the OHMS and OHMS SENSE input.
6. Short the four test leads together and zero the Model 196. Leave zero enabled for the entire test.
7. Connect OHMS HI and OHMS SENSE HI of the Model 196 to the common terminal (jumper). It is recommended that the physical connections be made at columns 1 and 12 as shown in Figure 4-2.
8. Connect OHMS LO and OHMS SENSE LO to the high (H) terminal post of ROW A.
9. Feed the test leads through the cable clamp of the matrix card and push the card all the way into the mainframe. Tighten the two spring loaded screws to completely mate the card with the backplane.
10. Turn on the Model 707 and program it to close crosspoint A1 (ROW A, COLUMN 1), and verify that the resistance of this path is <1.5Ω.
11. Open crosspoint A1, and close A2. Verify that the resistance of this path is <1.5Ω.
12. Open crosspoint A2, and close A3. Verify that the resistance of this path is <1.5Ω.
13. Using the basic procedure of steps 10 through 12, check the resistance of ROW A high (H) terminal paths for COLUMNS 4 through 12 (crosspoints A4 through A12).
14. Turn the Model 707 off and pull the matrix card out of the mainframe approximately 6" in order to gain access to the terminals.
15. Move the OHMS LO and OHMS SENSE LO test leads to the low (L) terminal of ROW A.
16. Repeat steps 9 through 12 to check the low (L) terminal paths of ROW A.
17. Turn the Model 707 off and move the OHMS LO and OHMS SENSE LO test leads to the guard (G) terminal of ROW A.
18. Repeat steps 10 through 12 to check the guard (G) terminal paths of ROW A.
19. Repeat the basic procedure in steps 1 through 18 for ROWS B through H.

Table 4-1. Verification Equipment

Description	Model	Specifications	Application
DMM	Keithley 196	300Ω; 0.01%	Path resistance
Electrometer w/voltage source	Keithley 617	10pA, 100pA; 1.6% 100V source; 0.2%	Offset current isolation
Nanovoltmeter	Keithley 181	2mV; 0.015%	Contact potential
Triax cable (unterminated)	Keithley 7025	—	Offset current isolation
Low thermal cable (unterminated)	Keithley 1484	—	Contact potential

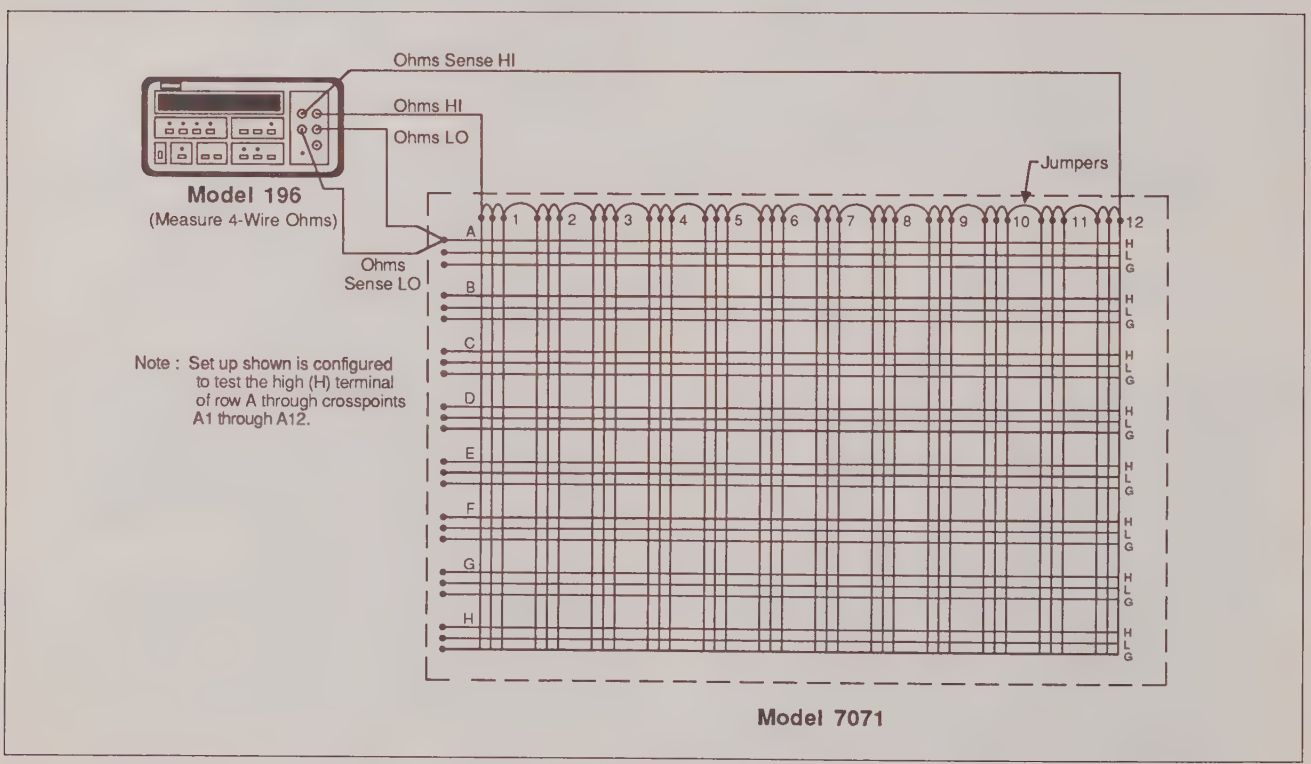


Figure 4-2. Path Resistance Testing

4.4.4 Offset Current Tests

These tests check leakage current between high (H) and low (L) (differential offset current) and from high and low to guard (G) (common mode offset current) of each pathway. In general, these tests are performed by simply measuring the leakage current with an electrometer. In the following procedure, the Model 617 is used to measure leakage current.

Perform the following procedure to check offset current:

1. Turn the Model 707 off if it is on.
2. Connect the Model 617 to a quick-disconnect terminal block as shown in Figure 4-3. Do not connect the terminal block to the matrix card at this time.
3. Place the matrix card in slot 1 of the Model 707, but do not slide it all the way into the mainframe.
4. On the Model 617, select the 20pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.
5. Connect the pre-wired terminal block to ROW A of the matrix card.
6. Feed the test leads through the cable clamp of the matrix card and push the card all the way into the mainframe. Tighten the two spring loaded screws to completely mate the card with the backplane.
7. Turn on the Model 707
8. Program the Model 707 to close crosspoint A1.
9. On the Model 617, disable zero check and verify that it is <20pA. This measurement is the leakage current of the pathway.
10. On the Model 617, enable zero check and on the Model 707, open crosspoint A1.
11. Repeat the basic procedure in steps 8 through 10 to check the rest of the pathways (crosspoints A2 through A12) of the row.
12. Turn off the Model 707 and slide out the matrix card far enough to gain access to the pre-wired terminal block.
13. Move the terminal block down to ROW B and repeat the basic procedure in steps 6 through 11 to check crosspoints B1 through B12.
14. Repeat the basic procedure in steps 12 and 13 for the remaining rows (ROWS C through H).
15. Turn off the Model 707, and slide the matrix card out far enough to gain access to the pre-wired terminal block.
16. Rewire the terminal block as shown in Figure 4-4.
17. Repeat steps 5 through 14 to check common mode offset current.

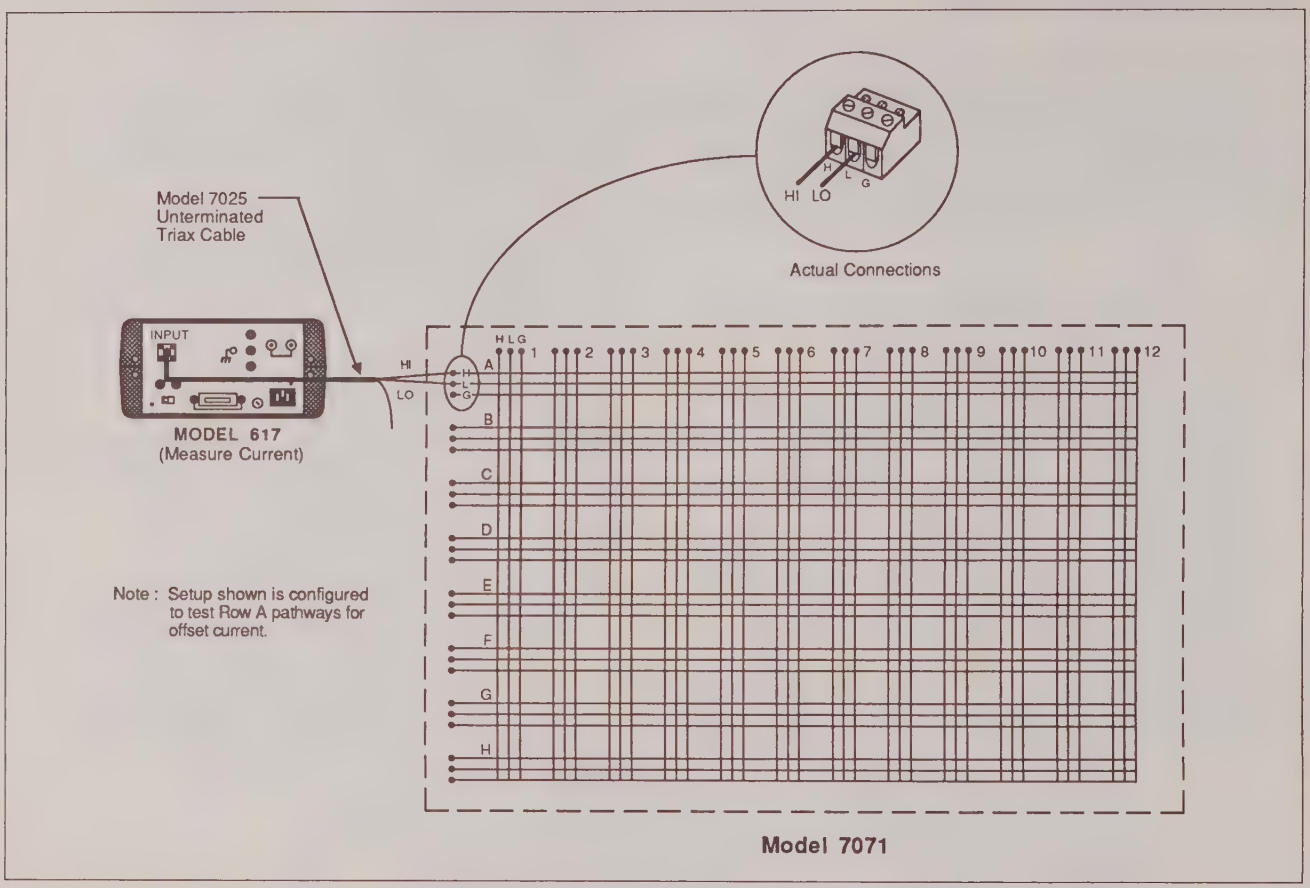


Figure 4-3. Differential Offset Current Testing

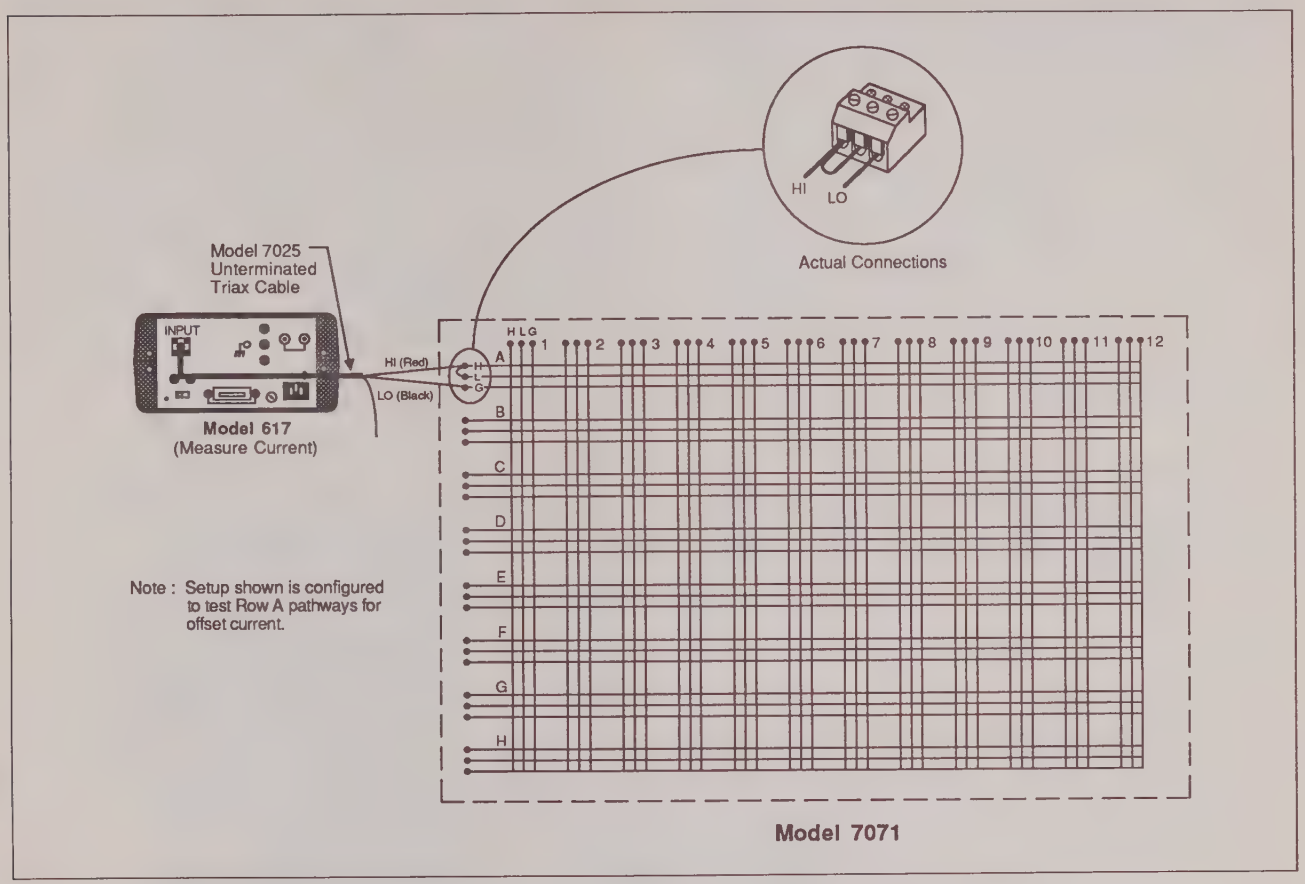


Figure 4-4. Common Mode Offset Current Testing

4.4.5 Contact Potential Tests

These tests check the EMF generated by each relay contact pair (H and L) for each pathway. The tests simply consist of using a nanovoltmeter (Model 181) to measure the contact potential.

Perform the following procedure to check contact potential of each path:

1. Turn the Model 707 off if it is on.
2. Set the Model 181 to the 2mV range, short the input leads and press ZERO to null out internal offset. Leave ZERO enabled for the entire procedure.
3. Connect the Model 181 to a quick-disconnect terminal block as shown in the illustration caption of Figure 4-5. Do not connect the terminal block to the matrix card at this time.
4. Place the matrix card in slot 1 of the Model 707, but do not slide it all the way into the mainframe.
5. Connect the pre-wired terminal block to ROW A of the matrix card.
6. Feed the test leads through the cable clamp of the matrix card and push the card all the way into the mainframe. Tighten the two spring loaded screws to completely mate the card with the backplane.
7. Turn on the Model 707
8. Program the Model 707 to close crosspoint A1.
9. Verify that the reading on the Model 181 is $<5\mu V$. This measurement is the contact potential of the pathway.
10. From the Model 707, open crosspoint A1.
11. Repeat the basic procedure in steps 8 through 10 to check the rest of the pathways (crosspoints A2 through A12) of the row.
12. Turn off the Model 707 and slide out the matrix card far enough to gain access to the pre-wired terminal block.

13. Move the terminal block down to ROW B and repeat the basic procedure in steps 6 through 11 to check crosspoints B1 through B12.

14. Repeat the basic procedure in steps 12 and 13 for the remaining rows (ROWS C through H).

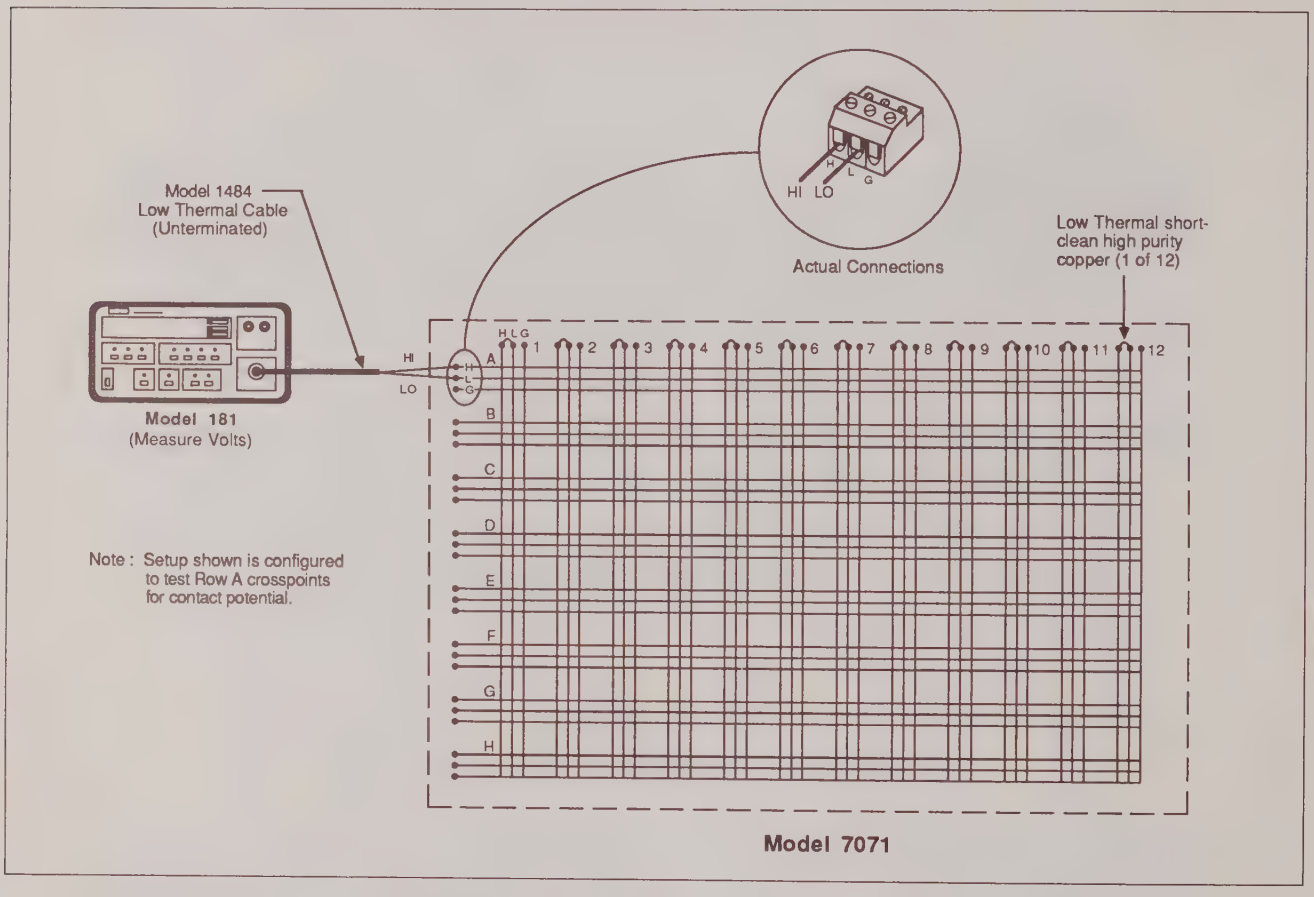


Figure 4-5. Contact Potential Testing

4.4.6 Path Isolation Tests

These tests check the leakage resistance (isolation) between adjacent paths. A path is defined as the high (H), low (L), guard (G) circuit from a row to a column that results by closing a particular crosspoint. In general, the test is performed by applying a voltage (+100V) across two adjacent paths and then measuring the leakage current accross the paths. The isolation resistance is then calculated as R = V/I. In the following procedure, the Model 617 functions as both a voltage source and an ammeter. In the V/I function, the Model 617 internally calculates the resistance from the known voltage and current levels and displays the resistive value.

NOTE

Refer to Figure 4-6 for the following procedure.

1. Turn the Model 707 off if it is on.
2. Connect the Model 617 to two quick-disconnect terminal blocks as shown in the illustration. Also, be sure to install the three jumper wires as shown. Do not connect the terminal blocks to the matrix card at this time.
3. On the matrix card, unplug all ROW terminal blocks from the PC board.
4. Place the matrix card in slot 1 of the Model 707, but do not slide it all the way into the mainframe.

WARNING

The following steps use high voltage (100V). Be sure to remove power from the circuit before making connection changes.

5. On the Model 617, select the 2pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.
6. Connect the two pre-wired terminal blocks to ROWS A and B of the matrix card.
7. Feed the test leads through the cable clamp of the matrix card and push the card all the way into the mainframe. Tighten the two spring loaded screws to completely mate the card with the backplane.
8. On the Model 617, select the 20pA range and release zero check.
9. On the Model 617, press suppress to cancel offset current and then enable zero check.
10. On the Model 617, set the voltage source for +100V, and select the 20nA current range. Make sure the voltage source is in standby.
11. Place the Model 617 in the V/I measurement function by pressing SHIFT OHMS.
12. Turn on the Model 707, and program it to close crosspoints A1 (ROW A, COLUMN 1) and B2 (ROW B, COLUMN 2).
13. On the Model 617, disable zero check and press OPERATE to source 100V.
14. After allowing the reading on the Model 617 to settle, verify that it is >10GΩ. This measurement is the leakage resistance (isolation) between ROW A, COLUMN 1 and ROW B, COLUMN 2.
15. Place the Model 617 in standby and enable zero check.
16. Turn off the Model 707, and slide the matrix card approximately six inches out of the mainframe to gain access to the terminal blocks.
17. Move the two pre-wired terminal blocks down one row so that they are located on ROW B and ROW C.
18. Reinstall the matrix card and turn on the Model 707.
19. Program the Model 707 to close crosspoints B2 and C3.
20. On the Model 617, disable zero check and press OPERATE to source 100V.
21. After allowing the reading on the Model 617 to settle, verify that it is >10GΩ.
22. Using Table 4-2 as a guide, repeat the basic procedure of steps 15 through 21 for the rest of the path pairs (test numbers 3 through 11 in the table).

Table 4-2. Path Isolation Tests

Test No.	Path Isolation	Test Equipment Location	Crosspoints Closed
1	Row A, col 1 to Row B, col 2	Row A and Row B	A1 and B2
2	Row B, col 2 to Row C, col 3	Row B and Row C	B2 and C3
3	Row C, col 3 to Row D, col 4	Row C and Row D	C3 and D4
4	Row D, col 4 to Row E, col 5	Row D and Row E	D4 and E5
5	Row E, col 5 to Row F, col 6	Row E and Row F	E5 and F6
6	Row F, col 6 to Row G, col 7	Row F and Row G	F6 and G7
7	Row G, col 7 to Row H, col 8	Row G and Row H	G7 and H8
8	Row G, col 8 to Row H, col 9	Row G and Row H	G8 and H9
9	Row G, col 9 to Row H, col 10	Row G and Row H	G9 and H10
10	Row G, col 10 to Row H, col 11	Row G and Row H	G10 and H11
11	Row G, col 11 to Row H, col 12	Row G and Row H	G11 and H12

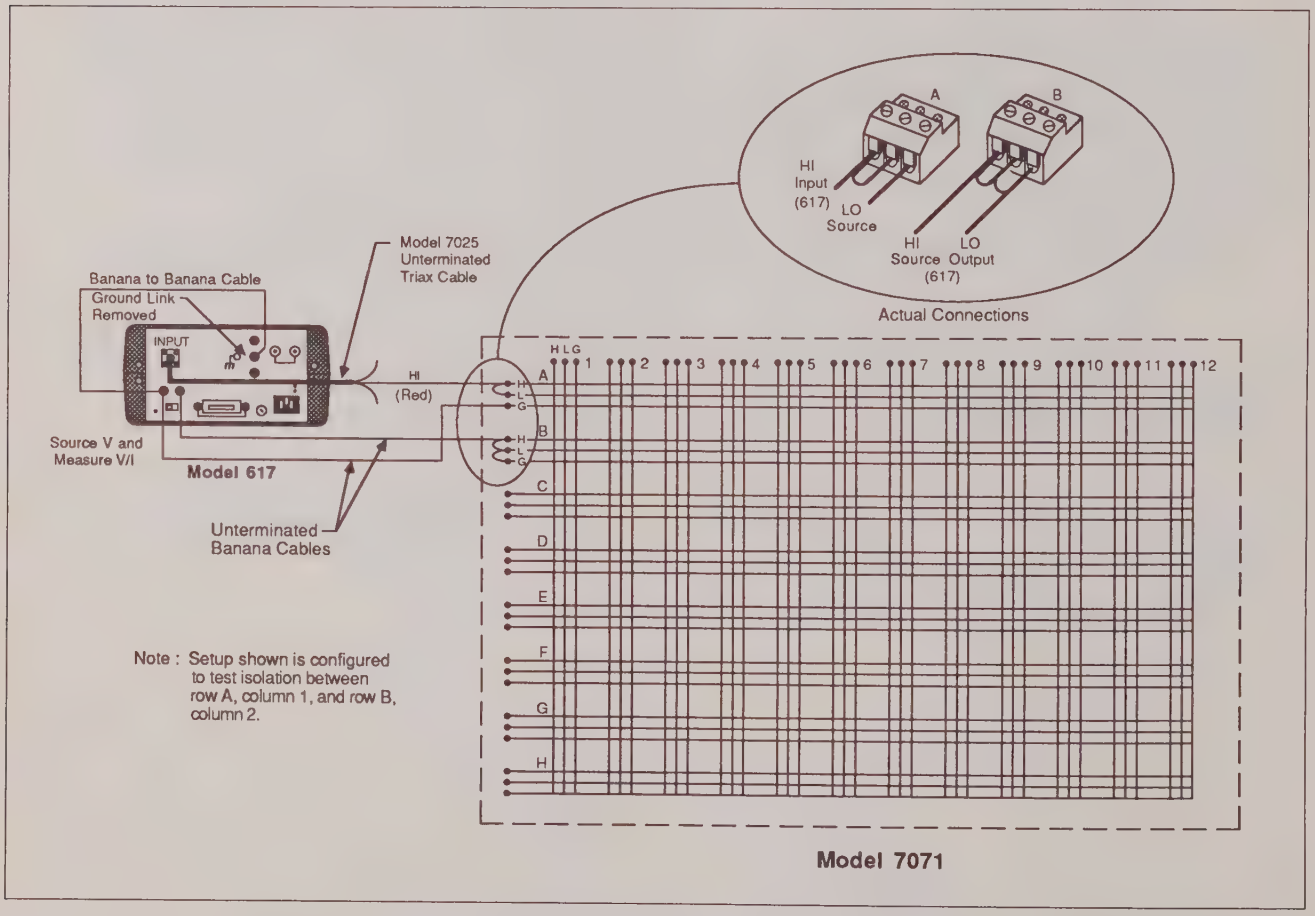


Figure 4-6. Path Isolation Testing (Guarded)

4.4.7 Differential and Common Mode Isolation Tests

These tests check the leakage resistance (isolation) between high (H) and low (L) (differential), and from high and low to guard (G) (common mode) of every row and column. In general, the test is performed by applying a voltage (100V) across the terminals and then measuring the leakage current. The isolation resistance is then calculated as R = V/I. In the following procedure, the Model 617 functions as a voltage source and an ammeter. In the V/I function, the Model 617 internally calculates the resistance from the known voltage and current levels and displays the resistance value.

1. Turn the Model 707 off if it is on.
2. Connect the Model 617 to a quick-disconnect terminal block as shown in Figure 4-7. Do not connect the terminal blocks to the matrix card at this time.
3. Place the matrix card in slot 1 of the Model 707, but do not slide it all the way into the mainframe.

WARNING
The following steps use high voltage (100V). Be sure to remove power from the circuit before making connection changes.

4. On the Model 617, select the 2pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.
5. On the Model 617, set the voltage source for +100V, and select the 200nA current range. Make sure the voltage source is still in standby.
6. Place the Model 617 in the V/I measurement function by pressing SHIFT OHMS.
7. With the Model 617 in standby, connect the pre-wired terminal block to ROW A of the matrix card.
8. Feed the test leads through the cable clamp of the matrix card and push the card all the way into the mainframe. Tighten the two spring loaded screws to completely mate the card with the backplane.
9. Turn on the Model 707, but do not program any crosspoints to close. All crosspoints must be open.
10. On the Model 617, disable zero check and press OPERATE to source 100V.
11. After allowing the reading on the Model 617 to settle, verify that it is >1GΩ. This measurement is the leakage resistance (isolation) of ROW A.
12. Place the Model 617 in standby and enable zero check.
13. Program the Model 707 to close crosspoint A1.
14. On the Model 617, disable zero check and press OPERATE to source 100V.
15. After allowing the reading on the Model 617 to settle, verify that it is also >1GΩ. This measurement checks the isolation of COLUMN 1.
16. Using Table 4-3 as a guide, repeat the basic procedure of steps 12 through 15 for the rest of the columns and rows (test numbers 3 through 20 of the table).
17. Turn the Model 707 off and slide the matrix card out of the mainframe far enough to gain access to the prewired terminal block.
18. Remove the terminal block from the matrix card and rewire the it as shown in Figure 4-8.
19. Repeat steps 7 through 16 to check common mode isolation.

Table 4-3. Differential and Common Mode Isolation Test

Test No.	Differential or Common Mode Test	Crosspoints Closed
1	ROW A	None
2	COLUMN 1	A1
3	COLUMN 2	A2
4	COLUMN 3	A3
5	COLUMN 4	A4
6	COLUMN 5	A5
7	COLUMN 6	A6
8	COLUMN 7	A7
9	COLUMN 8	A8
10	COLUMN 9	A9
11	COLUMN 10	A10
12	COLUMN 11	A11
13	COLUMN 12	A12
14	ROW B	A1 and B1
15	ROW C	A1 and C1
16	ROW D	A1 and D1
17	ROW E	A1 and E1
18	ROW F	A1 and F1
19	ROW G	A1 and G1
20	ROW H	A1 and H1

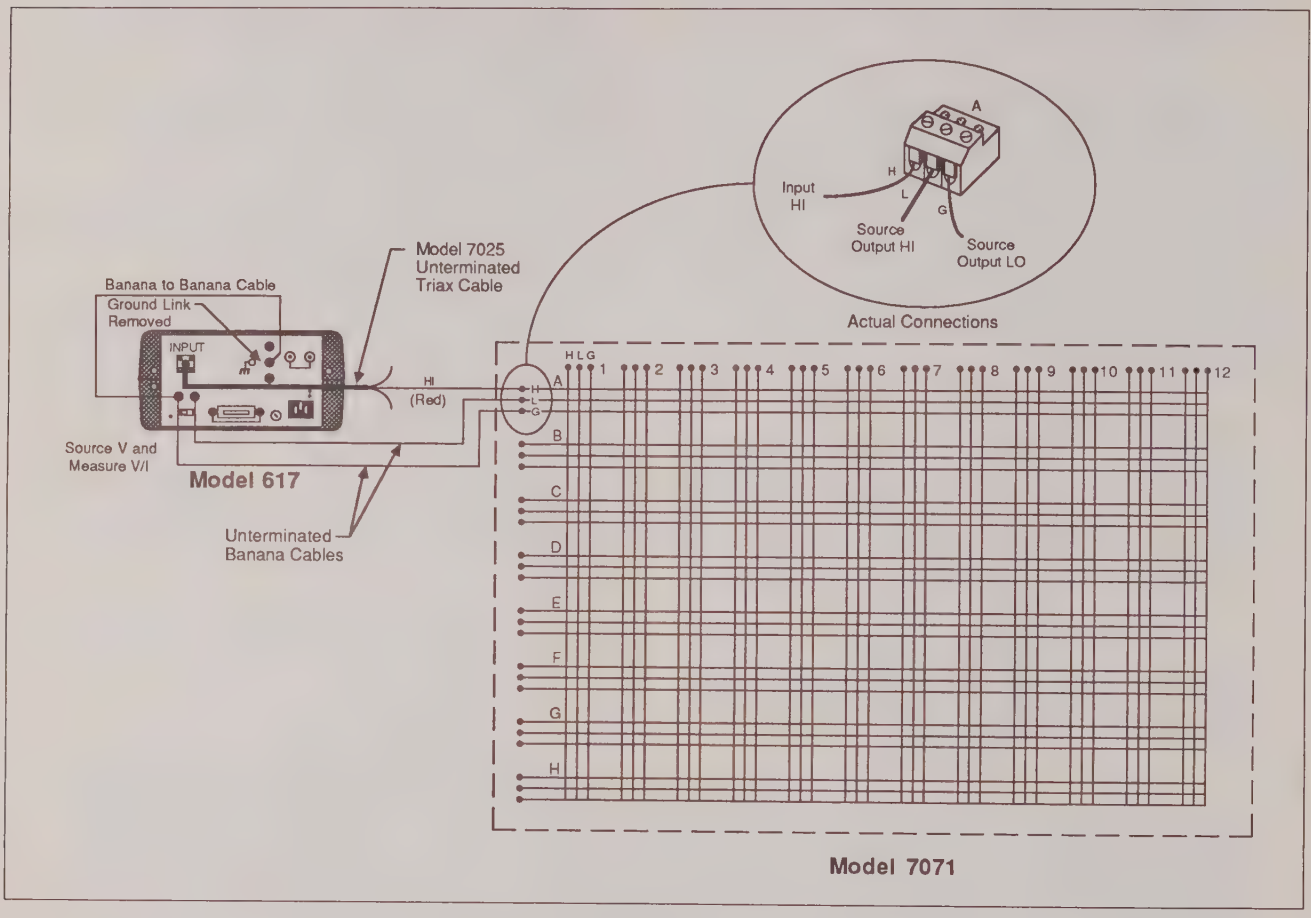


Figure 4-7. Differential Isolation Testing

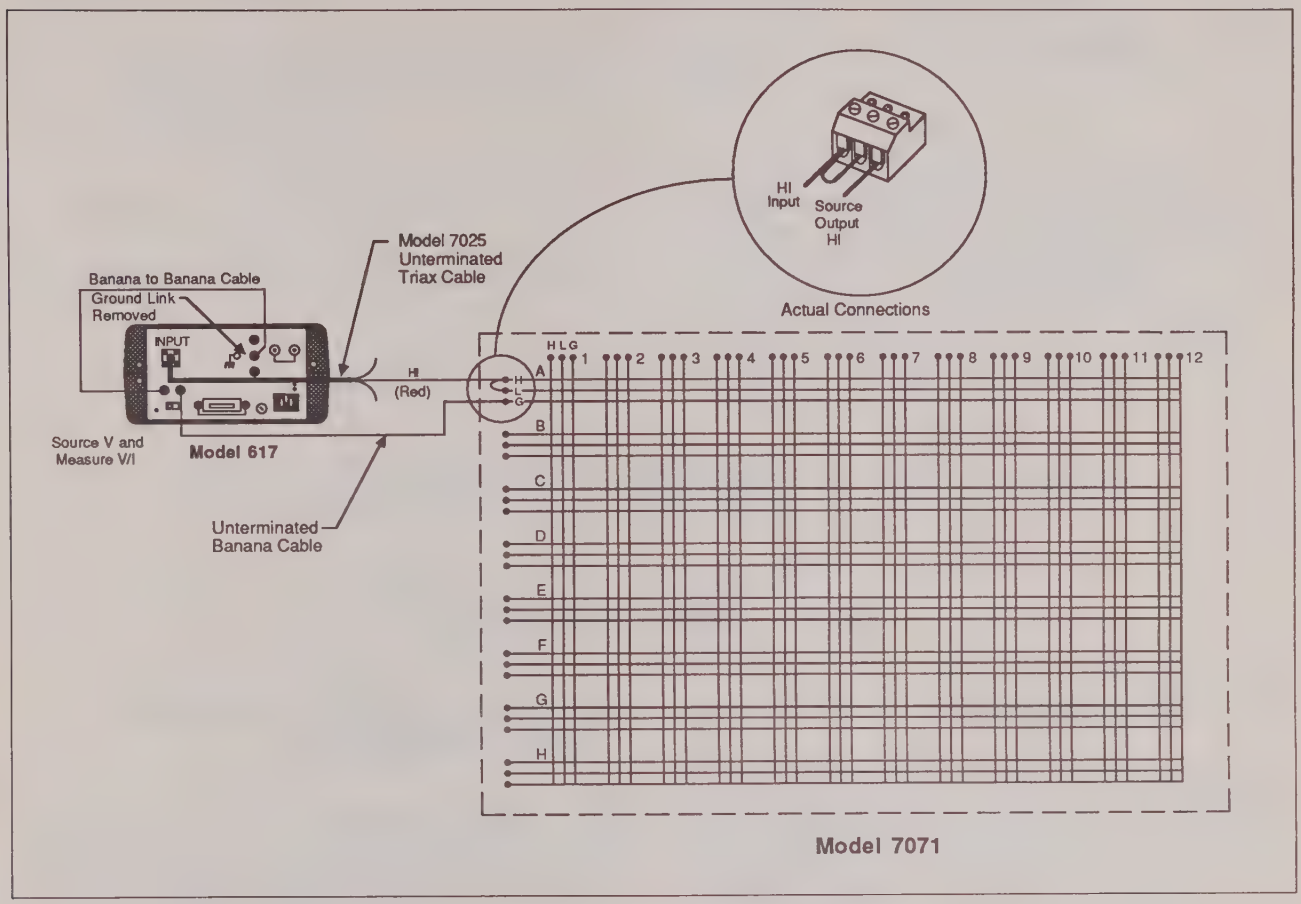


Figure 4-8. Common Mode Isolation Testing

4.5 PRINCIPLES OF OPERATION

The paragraphs below discuss the basic operating principles for the Model 7071 and can be used as an aid in troubleshooting the matrix card. The schematic drawing of the matrix card is shown on drawing number 7071-106, located at the end of Section 5.

4.5.1 Card Identification

Identification coding and a matrix configuration table is stored in an erasable programmable read-only memory (EPROM). This information is sent to the Model 707 so that it "knows" which type of matrix card is installed in that particular mainframe slot. This enables the Model 707 to send valid configuration data to the matrix card.

On power up, control line CARDSEL goes low turning on the EPROM (U27). That control line, as well as the other control lines from the Model 707, are buffered by U44. Lines CLK, NEXT ADDR and CLR ADDR along with counter U45 control the task of loading data from the EPROM into the parallel to serial shift register (U43). Data sent from U47 to the Model 707 via the IDDATA line is strobed by the CLK control line. The timing diagram in Figure 4-9. shows the first byte of identification data during the transfer sequence. For subsequent bytes, the CLRADDR line stays low.

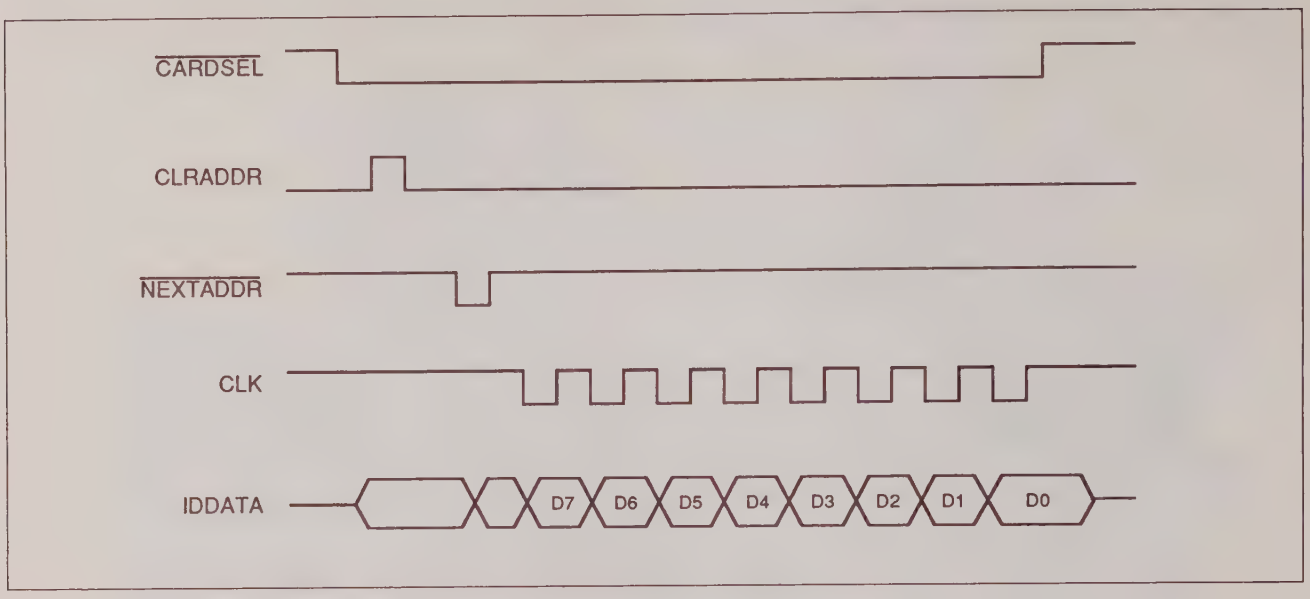


Figure 4-9. IDDATA Timing Diagram

4.5.2 Switching Circuitry

Matrix configuration data is sent from the Model 707 via the RELAY DATA control line and serially loaded into the 12 shift registers (U30 through U41). The matrix card relays configure accordingly when the registers receive the STROBE signal from the Model 707. A relay is energized when a register output is low (connected to digital common). A register output is low when a "high" data bit is clocked into it (i.e. inverting drivers).

4.5.3 Power Up Safeguard

To prevent relays from inadvertantly energizing and causing possible damage during power up, a safeguard circuit has been incorporated into the design. The protection circuit is comprised of a dual NAND gate (U42) and an RC network (R1, C20 and CR1). The time constant of the RC network keeps the the output of the NAND gate high during the power up sequence. This high signal is applied to the OEN input of the shift registers keeping the relays de-energized. After the capacitor of the RC network charges, a STROBE signal will then force the output of the NAND gate low allowing configured relays to energize.

4.6 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS and other high-impedance devices are subject to possible static discharge damage because of the high-impedance levels involved. The following precautions pertain specifically to static-sensitive devices. However, since many devices in the Model 7071 are static-sensitive, it is recommended that they all be treated as static-sensitive.

1. Such devices should be transported and handled only in containers specially designed to prevent or dissipate static build-up. Typically, these devices will be received in anti-static containers made of plastic or foam. Keep these parts in their original containers until ready for installation.
2. Revove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap while working with these devices.
3. Handle the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the device is to be inserted must first be grounded to the bench or table.
5. Use only anti-static type de-soldering tools and grounded-tip soldering irons.

4.7 TROUBLESHOOTING

The Keithley Model 7070 Universal Adapter Card is an extender card that allows access to circuit components of the Model 7071 during troubleshooting.

4.7.1 Recommended Equipment

Table 4-4 summarizes the equipment necessary for general troubleshooting.

4.7.2 Troubleshooting Procedure

Table 4-5 outlines the troubleshooting procedure for the matrix card.

CAUTION

Contamination will degrade the performance of the matrix card. To avoid contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card, and do not touch the board surfaces or components. On "rack and panel" connectors and quick disconnect terminal blocks, do not touch areas adjacent to the electrical contacts.

Table 4-4. Recommended Troubleshooting Equipment

Description	Application
DMM (Keithley 196)	Measure DC voltage
Dual-trace, triggered sweep oscilloscope, DC to 50MHz	Check clock and logic pulses
Extender Card (Keithley 7070)	Allow circuit access

Table 4-5. Troubleshooting Summary*

Step	Item/Component	Comment	Required Condition
1	TP1	+6V supply	+6V DC
2	TP3	+5V supply	+5V DC
3	TP5	CLR ADDR line**	High logic pulse at beginning of each card identification byte transfer sequence (upon power up).
4	TP4	$\overline{\text{NEXT ADDR}}$ line**	Low logic pulse before each byte transfer.
5	TP9	CLK line	1.79MHz clock
6	TP6	IDDATA line**	Card identification logic pulse train (on power up).
7	TP10	Power up safeguard	Remains high during power up
8	TP8	RELAY DATA line	Logic pulse train to load relay configuration resistors.
9	TP7	STROBE line	High logic pulse to strobe relay configuration registers.
10	U30 thru U41, pins 11 thru 18	Relay Drivers	+6V for open crosspoints ≈0V for closed crosspoints

*All measurements referenced to digital common (TP2)
**See Figure 4-9

SECTION 5
Replaceable Parts

5.1 INTRODUCTION

This section contains a list of replaceable electrical and mechanical parts for the Model 7071, as well as a component layout drawing and schematic diagram of the matrix card.

5.2 PARTS LISTS

Electrical parts are listed in order of circuit designation in Table 5-1. Table 5-2 summarizes miscellaneous parts.

5.3 ORDERING INFORMATION

To place a parts order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see the inside front cover for addresses). When ordering parts, be sure to include the following information:

1. Matrix card model number (7071)
2. Card serial number
3. Part description
4. Circuit description, if applicable
5. Keithley part number

5.4 FACTORY SERVICE

If the matrix card is to be returned to Keithley Instruments for repair, perform the following:

1. Complete the service form at the back of this manual and include it with the card.
2. Carefully pack the card in the original packing carton.
3. Write ATTENTION REPAIR DEPT on the shipping label.

Note: It is not necessary to return the matrix mainframe with the card.

5.5 COMPONENT LAYOUT AND SCHEMATIC DIAGRAM

Figure 5-1 shows a component layout of the Model 7071, while Figure 5-2 shows a schematic diagram.

TABLE 5-1. MODEL 7071, PARTS LIST

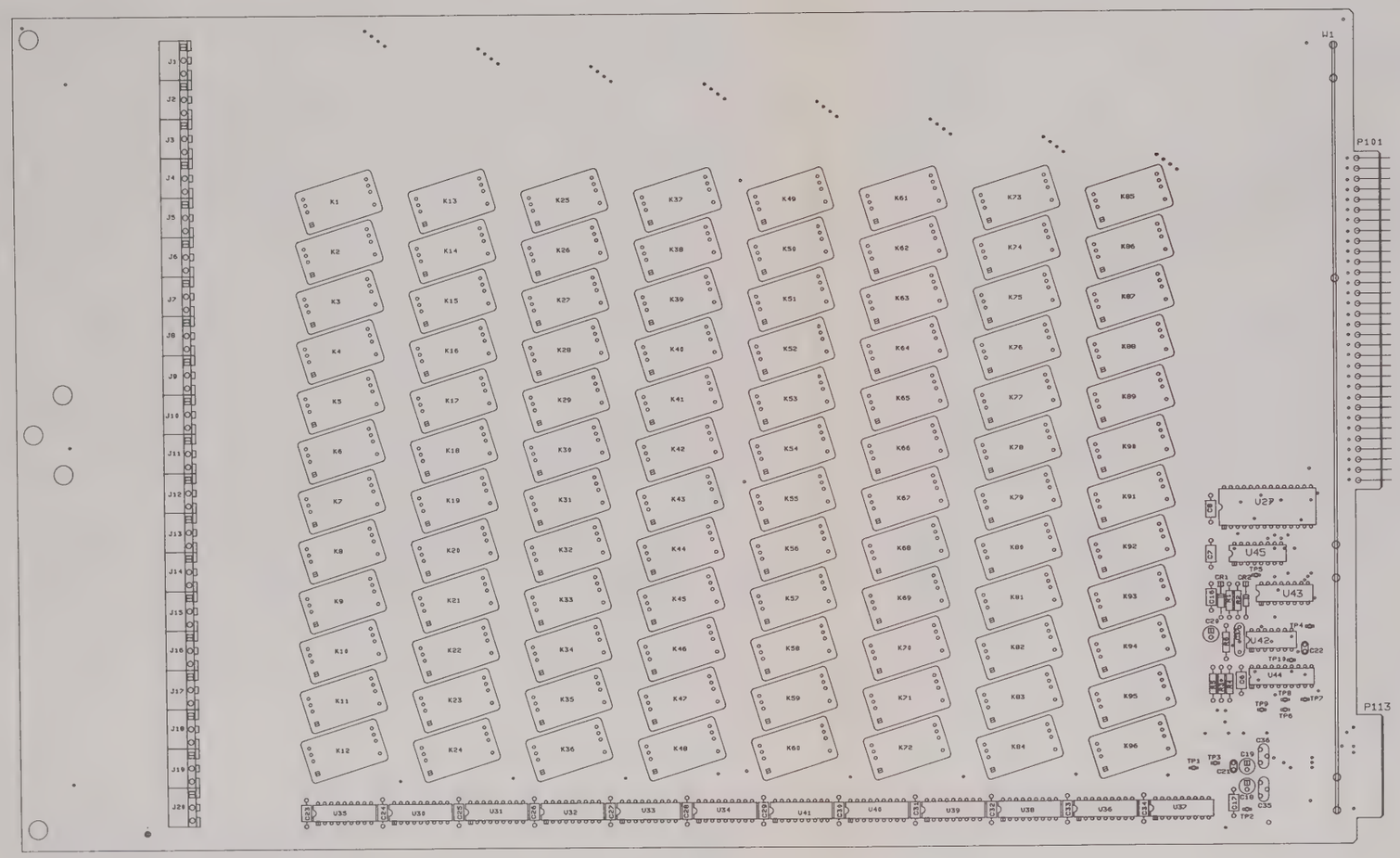
CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART NO.
C18..C20	CAP,10uF,-20+100%,25V,ALUM ELEC	C-314-10
C21,C22	CAP,.01uF,20%,50V,CERAMIC	C-237-.01
C23..C34		
C35,C36	CAP,270pF,20%,100V,CERAMIC/FERRITE	C-386-270P
C37	CAP,.01uF,10%,1000V,CERAMIC	C-64-.01
C6..C8,C16,C17,	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
CR1	DIODE,SILICON,1N4148 (DO-35)	RF-28
CR2	DIODE,SCHOTTKY,1N5711	RF-69
J1..J20	CONN,3 PIN	CS-570-3
J21,J22	SOCKET,CONNECTOR	CS-593
K1..K96	RELAY	RL-67
R1	RES,47K,5%,1/4W,COMPOSITION OR FILM	R-76-47K
R2	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
R3	RES,120K,5%,1/4W,COMPOSITION OR FILM	R-76-120K
R4	RES,11K,5%,1/4W,COMPOSITION OR FILM	R-76-11K
R5	RES,910,5%,1/4W,COMPOSITION OR FILM	R-76-910
R6	RES,200,5%,1/4W,COMPOSITION OR FILM	R-76-200
TP1..TP10	CONN,TEST POINT	CS-553
U27	PROGRAM	7071-800
U30..U41	IC,8-BIT SERIAL-IN/LTCH DRIVE,UCN-5841A	IC-536
U42	IC,QUAD 2 INPUT NAND,74HCT00	IC-399
U43	IC,8 BIT PARALLEL TO SERIAL,74HCT165	IC-548
U44	IC,OCTAL BUFFER/LINE DRIVER,74HCT244	IC-483
U45	IC,12 STAGE BINARY COUNTER,74HCT4040	IC-545
W1	STIFFENER,BOARD	J-16

TABLE 5-2. MODEL 7071, MISCELLANEOUS, PARTS LIST

QUANTITY	DESCRIPTION	KEITHLEY PART NO.
2	UPPER CLAMP ASSEMBLY	-
2	UPPER CLAMP	7071-305
2	RUBBER STRIP	7071-307-1
2	LOWER CLAMP ASSEMBLY	-
2	LOWER CLAMP	7071-306
2	RUBBER STRIP	7071-307-1
1	HANDLE	HH-33-1
1	CONNECTOR STRIP	CS-576-60
1	SOCKET (FOR U27)	SO-69
1	SHIELD, REAR	7071-311
8	STANDOFFS	7071-310

LTR.	ECO NO.	REVISION	ENG.	DATE
B	12349	RELEASED		9-14-87
C	12566	REVISED		11-4-88

NO. 7071-100



NOTE:

FOR COMPONENT INFORMATION, REFER TO BILL OF MATERIAL (7071-000-00).

MODEL	NEXT ASSEMBLY	QTY.
7071	USED ON	

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 1-19-88	SCALE 1:1	TITLE COMPONENT LAYOUT, GENERAL PURPOSE MATRIX CARD
KEITHLEY KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139	XX=±.015 ANG.=±1°	DRN. CB	ENG. APPR.	
	XXX=±.005 FRAC.=±1/64	MATERIAL	D	NO. 7071-100
	SURFACE MAX. 63	FINISH		

Figure 5-1. Model 7071 Component Location Drawing, Dwg. No. 7071-100

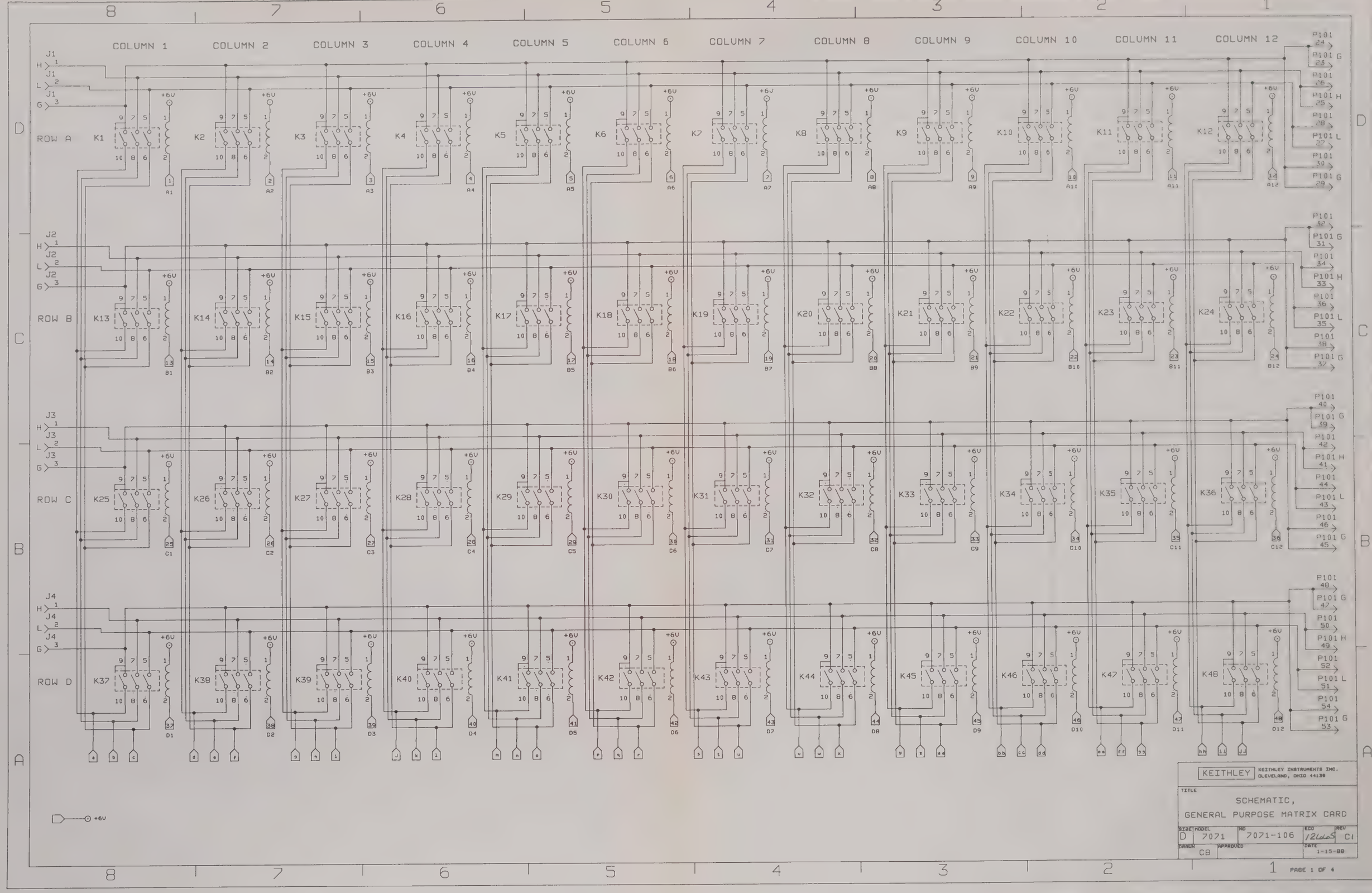


Figure 5-2. Model 7071 Schematic Diagram, Dwg. No. 7071-106 (sheet 1 of 4)

COLUMN 1 COLUMN 2 COLUMN 3 COLUMN 4 COLUMN 5 COLUMN 6 COLUMN 7 COLUMN 8 COLUMN 9 COLUMN 10 COLUMN 11 COLUMN 12

ROW E: K49 K50 K51 K52 K53 K54 K55 K56 K57 K58 K59 K60

ROW F: K61 K62 K63 K64 K65 K66 K67 K68 K69 K70 K71 K72

ROW G: K73 K74 K75 K76 K77 K78 K79 K80 K81 K82 K83 K84

ROW H: K85 K86 K87 K88 K89 K90 K91 K92 K93 K94 K95 K96

J5 H 1, J5 L 2, J5 G 3 — P101 56, P101 G 55, P101 58, P101 H 57, P101 60, P101 L 59, P101 62, P101 G 61

J6 H 1, J6 L 2, J6 G 3 — P101 64, P101 G 63, P101 66, P101 H 65, P101 68, P101 L 67, P101 70, P101 G 69

J7 H 1, J7 L 2, J7 G 3 — P101 72, P101 G 71, P101 74, P101 H 73, P101 76, P101 L 75, P101 78, P101 G 77

J8 H 1, J8 L 2, J8 G 3 — P101 80, P101 G 79, P101 82, P101 H 81, P101 84, P101 L 83, P101 86, P101 G 85

COLUMN 1: J9 3, J9 1, J9 2
COLUMN 2: J10 3, J10 1, J10 2
COLUMN 3: J11 3, J11 1, J11 2
COLUMN 4: J12 3, J12 1, J12 2
COLUMN 5: J13 3, J13 1, J13 2
COLUMN 6: J14 3, J14 1, J14 2
COLUMN 7: J15 3, J15 1, J15 2
COLUMN 8: J16 3, J16 1, J16 2
COLUMN 9: J17 3, J17 1, J17 2
COLUMN 10: J18 3, J18 1, J18 2
COLUMN 11: J19 3, J19 1, J19 2
COLUMN 12: J20 3, J20 1, J20 2

+6V

KEITHLEY — KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139

TITLE: SCHEMATIC, GENERAL PURPOSE MATRIX CARD

SIZE	MODEL	NO	ECO	REV
D	7071	7071-106	12465	C1

DRAWN: CB — APPROVED: — DATE: 1-15-88

PAGE 2 OF 4

Figure 5-2. Model 7071 Schematic Diagram, Dwg. No. 7071-106 (sheet 2 of 4)

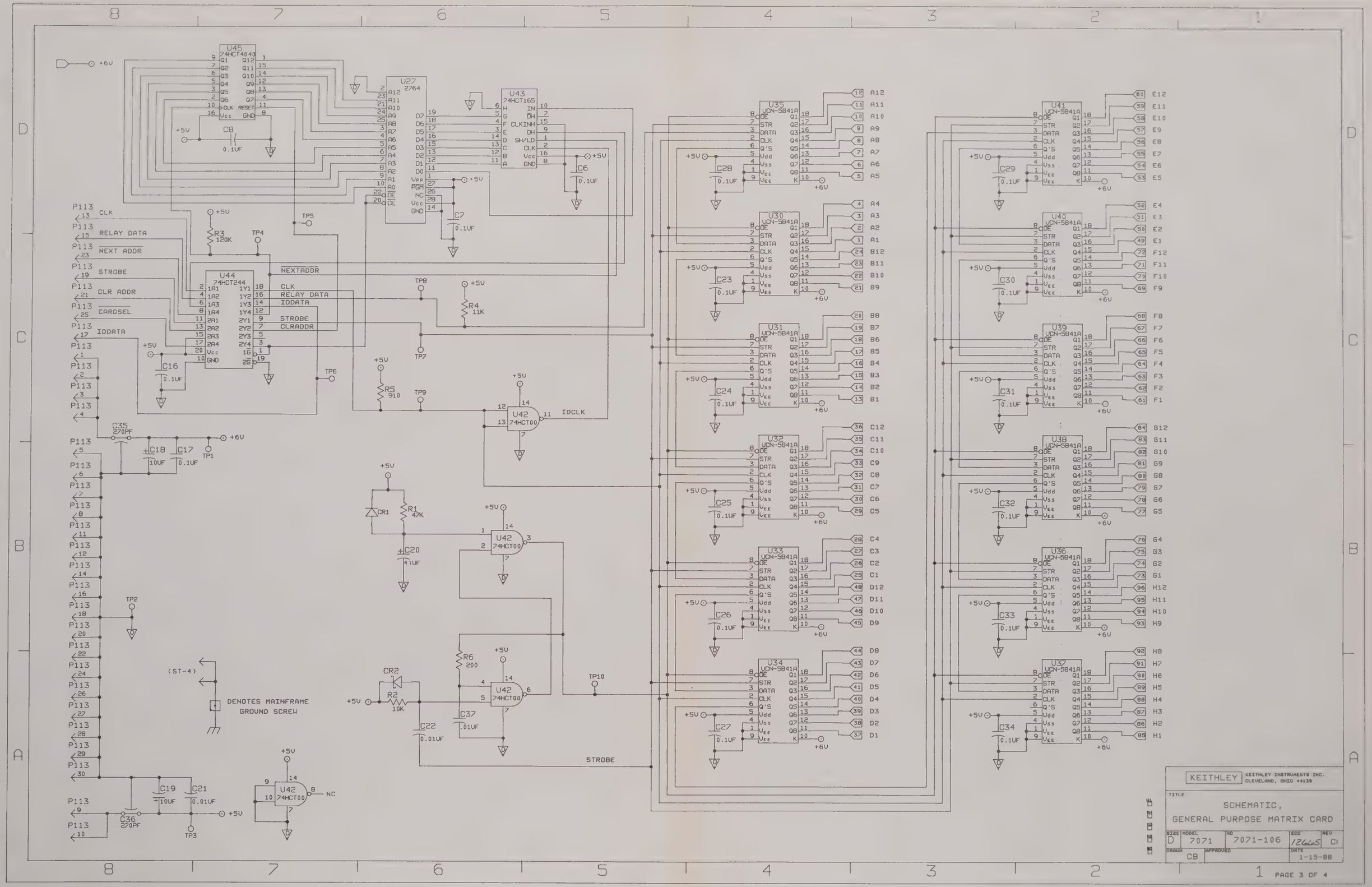


Figure 5-2. Model 7071 Schematic Diagram, Dwg. No. 7071-106 (sheet 3 of 4)

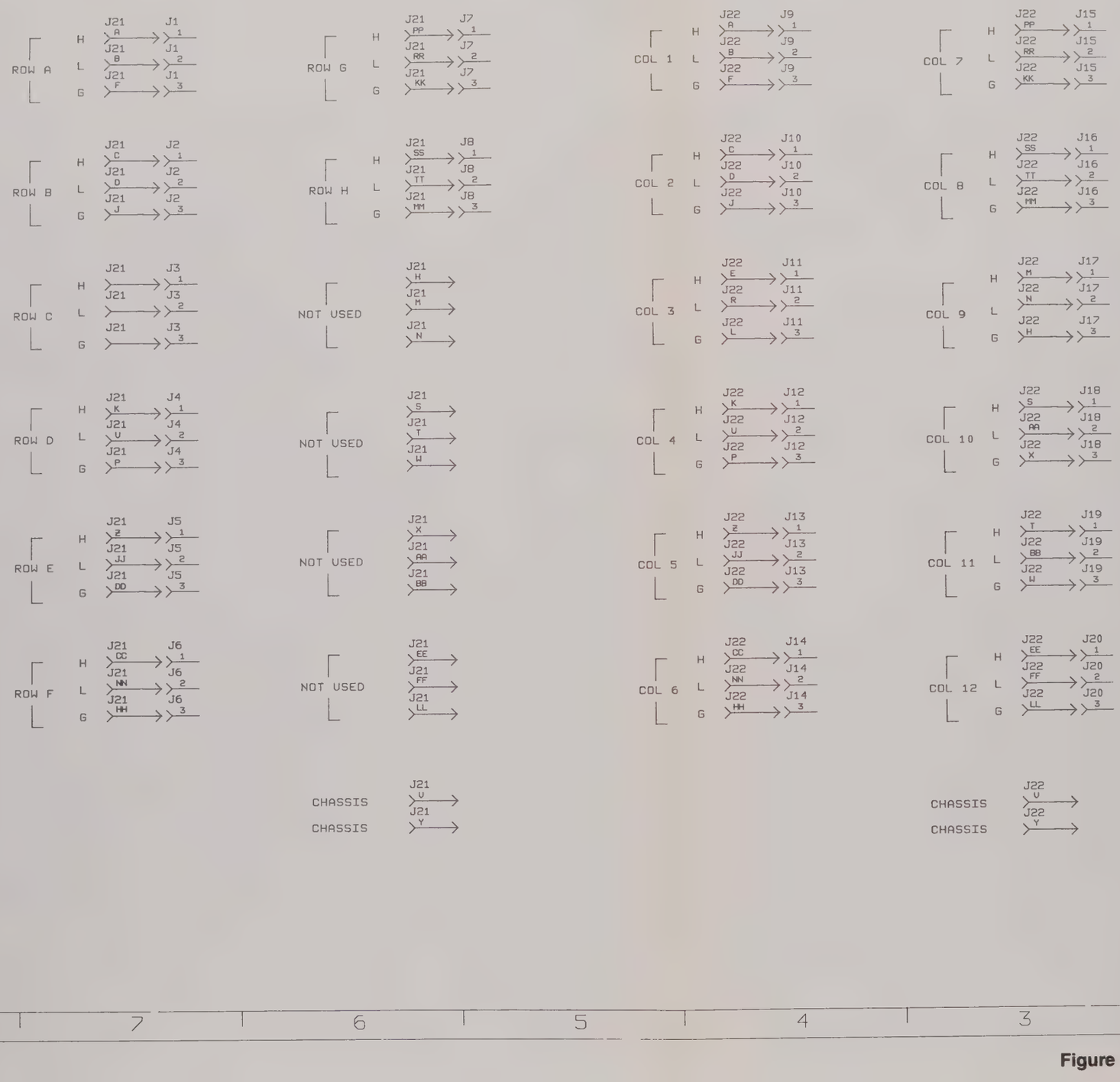

ROW A
H J21 A → J1 1
L J21 B → J1 2
G J21 F → J1 3
ROW B
H J21 C → J2 1
L J21 D → J2 2
G J21 J → J2 3
ROW C
H J21 → J3 1
L J21 → J3 2
G J21 → J3 3
ROW D
H J21 K → J4 1
L J21 U → J4 2
G J21 P → J4 3
ROW E
H J21 Z → J5 1
L J21 JJ → J5 2
G J21 DD → J5 3
ROW F
H J21 CC → J6 1
L J21 NN → J6 2
G J21 HH → J6 3
ROW G
H J21 PP → J7 1
L J21 RR → J7 2
G J21 KK → J7 3
ROW H
H J21 SS → J8 1
L J21 TT → J8 2
G J21 MM → J8 3
NOT USED
J21 H
J21 M
J21 N
NOT USED
J21 S
J21 T
J21 W
NOT USED
J21 X
J21 AA
J21 BB
NOT USED
J21 EE
J21 FF
J21 LL
CHASSIS J21 U
CHASSIS J21 Y
COL 1
H J22 A → J9 1
L J22 B → J9 2
G J22 F → J9 3
COL 2
H J22 C → J10 1
L J22 D → J10 2
G J22 J → J10 3
COL 3
H J22 E → J11 1
L J22 R → J11 2
G J22 L → J11 3
COL 4
H J22 K → J12 1
L J22 U → J12 2
G J22 P → J12 3
COL 5
H J22 Z → J13 1
L J22 JJ → J13 2
G J22 DD → J13 3
COL 6
H J22 CC → J14 1
L J22 NN → J14 2
G J22 HH → J14 3
COL 7
H J22 PP → J15 1
L J22 RR → J15 2
G J22 KK → J15 3
COL 8
H J22 SS → J16 1
L J22 TT → J16 2
G J22 MM → J16 3
COL 9
H J22 M → J17 1
L J22 N → J17 2
G J22 H → J17 3
COL 10
H J22 S → J18 1
L J22 AA → J18 2
G J22 X → J18 3
COL 11
H J22 T → J19 1
L J22 BB → J19 2
G J22 W → J19 3
COL 12
H J22 EE → J20 1
L J22 FF → J20 2
G J22 LL → J20 3
CHASSIS J22 U
CHASSIS J22 Y
KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139
TITLE
SCHEMATIC,
GENERAL PURPOSE MATRIX CARD
SIZE D
MODEL 7071
NO 7071-106
ECO 12665
REV C1
DRAWN CB
APPROVED
DATE 1-18-88
PAGE 4 OF 4

Figure 5-2. Model 7071 Schematic Diagram, Dwg. No. 7071-106 (sheet 4 of 4)

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SERVICE FORM

Model No. _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

Name _____ **Phone** _____

Company _____

Address _____

City _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)_____

What power line voltage is used?_____ Variation?_____

Frequency?_____ Ambient Temperature?_____°F.

Variation? _____°F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

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Model 7072 Addendum

The following change information is supplied as a supplement to this manual in order to provide the user with the latest improvements and corrections in the shortest possible time. It is recommended that this information be placed at the end of Section 4 of the matrix card instruction manual.

Copper cladding has been added to the rear shield of the matrix card in order to provide increased protection from static discharge. The copper shield is electrically connected to chassis ground of the matrix card by a jumper wire.

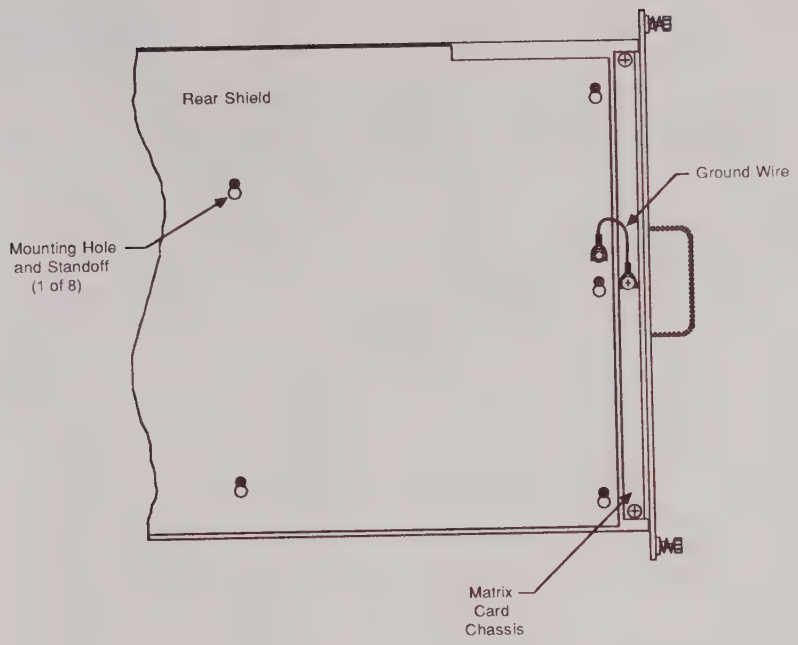
In order to service the matrix card, it may be necessary to remove the rear shield. Referring to the illustration, perform the following procedure to remove and reinstall the rear shield:

1. Disconnect the jumper wire from the matrix card chassis. The wire is secured to the matrix card chassis with a screw.
2. The rear shield is secured to the matrix card by eight standoffs. Carefully slide the rear shield upward until the eight standoffs align with the large clearance holes in the shield and remove the shield.
3. To reinstall the shield, reverse the above procedure. Make sure the metal side of the shield is facing outward.

CAUTION

Failure to observe the following precautions could result in damage not covered by the warranty:

1. **The shield must be installed such that the metal side is facing away from the matrix card. Backward installation will cause PC board connections to short out against the metal shield.**
2. **The jumper wire must be connected as shown in order to provide circuit protection from static discharge.**


Rear Shield
Ground Wire
Mounting Hole
and Standoff
(1 of 8)
Matrix
Card
Chassis

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Model 7072 Semiconductor Matrix Card Instruction Manual

Contains Operating and Servicing Information

Publication Date: March 1988
Document Number: 7072-901-01 Rev. B

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Keithley Instruments, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

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Instruction Manual
Model 7072
Semiconductor Matrix Card

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Cleveland, Ohio, U.S.A.
Document Number: 7072-901-01

SAFETY PRECAUTIONS

The following safety precautions should be observed before using the Model 7072 and the associated instruments.

This matrix card is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over this manual carefully before using the matrix card.

Exercise extreme caution when a shock hazard is present at the test circuit. User-supplied lethal voltages may be present on the card connector jacks. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS or 42.4V peak are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Do not exceed 200V between any two pins or between any pin and earth ground.

Inspect the connecting cables and test leads for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the test cables or any instruments while power is applied to the circuit under test. Turn off the power and discharge any capacitors before connecting or disconnecting cables from the matrix card.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

Do not exceed the maximum allowable input of the matrix card, as defined in the specifications and operation section of this manual.

SPECIFICATIONS

Rows:	Low Current (A - B)	General Purpose (C - F)	C-V (G - H)
CROSSPOINT CONFIGURATION:	2-pole Form A	2-pole Form A	1-pole Form A, Common Guard
OFFSET CURRENT:	<1 pA	<20 pA	<20 pA
PATH ISOLATION:			
Resistance:	$>10^{13}\ \Omega$	$>10^{12}\ \Omega$	$>10^{12}\ \Omega$
Capacitance (nominal):	0.4 pF	1 pF	0.6 pF
1 MHz, 1 MΩ load (typical):	50dB	40 dB	50 dB
3dB BANDWIDTH (typical), 1MΩ Load:	15 MHz	8 MHz	5 MHz
RELAY DRIVE CURRENT (per crosspoint):	40 mA	60 mA	80 mA

MATRIX CONFIGURATION: 8 rows by 12 columns.

CONNECTOR TYPE: Three lug triaxial (Signal, Guard, Chassis).

MAXIMUM SIGNAL LEVEL: 200V, 1A carry/ 0.5A switched, 10VA peak (resistive load).

COMMON MODE VOLTAGE: 200V maximum between any 2 pins or chassis.

CONTACT LIFE:

Cold Switching: 10^7 closures.

At Maximum Signal Level: 10^5 closures.

PATH RESISTANCE (per conductor): <1Ω initial, <3.5Ω at end of contact life.

CONTACT POTENTIAL: <20μV per crosspoint (Signal to Guard).

RELAY SETTLING TIME: <15ms.

INSERTION LOSS (1MHz, 50Ω source, 1MΩ load): 0.1dB typical.

ENVIRONMENT:

OFFSET CURRENT and PATH ISOLATION Specifications: 23°C, <60% R.H.

Operating: 0° to 50°C, up to 35°C at 70% R.H.

Storage: −25 to +65°C.

ACCESSORY SUPPLIED: Instruction manual.

ACCESSORIES AVAILABLE:

Model 7078-TRX-BNC: 3-Lug Triax to BNC Adapter

Model 7078-TRX-T: 3-Lug Triax Tee Adapter

Model 7078-TRX-3: 3-Lug Triax Cable, 0.9m (3 ft.)

Model 7078-TRX-10: 3-Lug Triax Cable, 3m (10 ft.)

Model 7078-TBC: 3-Lug Female Triax Bulkhead Connector with Cap

Model 7078-CSHP: Cable Set to connect 7072 to HP 4145

Specifications subject to change without notice.

Contains information on Model 7072 features, specifications, and accessories.

SECTION 1
General Information

Details installation of the Model 7072 Semiconductor Matrix Card within the Model 707 Switching Matrix, covers card connections, and also discusses measurement considerations.

SECTION 2
Operation

Gives four typical applications for the Model 7072, including combined quasistatic and high-frequency CV measurements, semiconductor switching matrix, van der Pauw resistivity measurements, and semiconductor parameter analysis.

SECTION 3
Applications

Contains performance verification procedures, troubleshooting information and principles of operation for the matrix card.

SECTION 4
Service Information

Lists replacement parts, and also includes component layout and schematic drawings for the Model 7072.

SECTION 5
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SECTION 1
General Information

1.1 INTRODUCTION

This section contains general information about the Model 7072 Semiconductor Matrix Card. The Model 7072 is designed for flexibility in switching semiconductor test setups. Two low-current pathways, and two C-V pathways in addition to four general-purpose pathways allow complete system versatility.

Section 1 is arranged in the following manner:

1.2 Features
1.3 Warranty Information
1.4 Manual Addenda
1.5 Safety Symbols and Terms
1.6 Specifications
1.7 Unpacking and Inspection
1.8 Repacking for Shipment
1.9 Optional Accessories
1.10 Coaxial Jumper Access

1.2 FEATURES

Key features of the Model 7072 Semiconductor Matrix Card include:

- 8 × 12 (eight row by 12 column) switching matrix.
- Two rows (A and B) with low-current offset for low-current measurements.
- Two dedicated rows (G and H) for CV measurements.
- Three-lug triax connectors for all row and columns allow guarding of each signal pathway to minimize the effects of stray capacitance, leakage current, and leakage resistance.
- Model 7072 cards can be connected together to expand the number of columns in the matrix.

1.3 WARRANTY INFORMATION

Warranty information is located on the inside front cover of this instruction manual. Should your Model 7072 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the matrix card for repair, be sure to fill out and include the service form at the back of this manual in order to provide the repair facility with the necessary information.

1.4 MANUAL ADDENDA

Any improvements or changes concerning the matrix card or manual will be explained in an addendum included with the the unit. Be sure to note these changes and incorporate them into the manual before using or servicing the unit.

1.5 SAFETY SYMBOLS AND TERMS

The following symbols and terms may be found on an instrument or used in this manual.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the matrix card. Such damage may invalidate the warranty.

1.6 SPECIFICATIONS

Model 7072 specifications may be found at the front of this manual. These specifications are exclusive of the matrix mainframe specifications, which are located in the Model 707 Instruction Manual.

1.7 UNPACKING AND INSPECTION

1.7.1 Inspection for Damage

Upon receiving the Model 7072, carefully unpack it from its shipping carton and inspect the card for any obvious signs of physical damage. Report any such damage to the shipping agent immediately. Save the original packing carton for possible future reshipment.

1.7.2 Shipment Contents

The following items are included with every Model 7072 order:

- Model 7072 Semiconductor Matrix Card.
- Model 7072 Instruction Manual.
- Coaxial jumper cables (4) for matrix expansion.
- Additional Accessories as ordered.

1.7.3 Instruction Manual

The Model 7072 Instruction Manual is three-hole drilled so that it can be added to the three-ring binder of the Model 707 Switching Matrix Instruction Manual. After removing the plastic wrapping, place the manual in the binder after the mainframe instruction manual. Note that a manual identification tab is included and should precede the matrix card instruction manual.

If an additional instruction manual is required, order the manual package, Keithley part number 7072-901-00. The manual package includes an instruction manual and any pertinent addenda.

1.8 REPACKING FOR SHIPMENT

Should it become necesary to return the Model 7072 for repair, carefully pack the card in its original packing carton or the equivalent, and include the following information:

- Advise as to the warranty status of the matrix card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.9 OPTIONAL ACCESSORIES

The following accessories are available to make connections to the Model 7072.

Model 6171 3-slot Male to 2-lug Female Triaxial Adapters—The Model 6171 allows male 2-lug triaxial cables to be connected to the Model 7072.

Model 7078-TRX-T 3-Lug Triax Tee Adapter—The Model 7078-TRX-T allows multiple triax connections to the Model 7072 column or row jacks.

Model 7078-TRX-BNC 3-Lug Triax to BNC Adapter—The Model 7078-TRX-BNC allows BNC cables to be connected to the Model 7072.

Model 7078-TRX Triaxial Cables—The Model 7078-TRX cables are terminated with 3-slot male triaxial connectors. The Model 7078-TRX-3 is 0.9m (3 ft.) in length, and the Model 7078-TRX-10 is 3m (10 ft.) long.

Model 7078-TBC 3-Lug Female Triax Bulkhead Connector with Cap—The Model 7078-TBC can be used for applications such as test fixtures.

Model 7078-CSHP Cable Set—The Model 7078-CSHP Cable Set includes the necessary cables and adapters to connect the Model 7072 to the Hewlett-Packard Model 4145 Semiconductor Parameter Analyzer. The Model 7078-CSHP includes four Model 7078-TRX-10 10ft. 3-lug triaxial cables, four Model 7051-10 10ft. BNC cables, and four Model 7078-TRX-BNC 3-lug triax to BNC adapters.

1.10 COAXIAL JUMPER ACCESS

Coaxial jumpers can be installed to expand rows A, B, G and H of the matrix using two or more Model 7072 Cards. An access door on the mainframe allows access to these jumpers. To allow access when the Model 707 is mounted in a rack, it is recommended that the Model 7079 Slide Rack Mount Kit be used.

SECTION 2
Operation

2.1 INTRODUCTION

This section contains information on matrix card connections, installation and matrix programming, and is arranged as follows:

2.2 **Handling Precautions:** Discusses precautions that should be taken when handling the card to avoid contamination that could degrade performance.

2.3 **Environmental Considerations:** Outlines environmental aspects of using the Model 7072.

2.4 **Card Installation and Removal:** Details installation in and removal from the Model 707 Switching Matrix mainframe.

2.5 **Connections:** Discusses card connectors, cables and adapters, and typical connections to other instrumentation.

2.6 **Matrix Configuration:** Discusses the switching matrix, as well as matrix expansion by connecting two or more cards together.

2.7 **Measurement Considerations:** Reviews a number of considerations when making low-level current and capacitance measurements.

2.2 HANDLING PRECAUTIONS

To maintain high impedance isolation, care should be taken when handling the matrix card to avoid contamination from such foreign materials as body oils. Such contamination can substantially lower leakage resistances, degrading performance. The areas of the card that are most sensitive to contamination are those associated with the Teflon® insulators. To avoid any possible contamination, always grasp the card by the handle or the card edges. Do not touch board surfaces, components, or card edge connectors.

Dirt build-up over a period of time is another possible source of contamination. To avoid this problem, operate the mainframe and matrix card only in a clean environment. If contamination is suspected,clean the card as discussed in Section 4. Also, the performance verification procedures in Section 4 can be used to test the card for low leakage resistances that could signal contamination.

2.3 ENVIRONMENTAL CONSIDERATIONS

For rated performance, the card should be operated within the temperature and humidity limits given in the specifications at the front of this manual. Note that current offset and path isolation values are specified within a lower range of limits than the general operating environment.

2.4 CARD INSTALLATION AND REMOVAL

Before making connections, the Model 7072 should be installed within the Model 707 Switching Matrix, as summarized below. Figure 2-1 shows the installation procedure.

WARNING

Turn off the mainframe power and disconnect the line cord before installing or removing matrix cards.

NOTE

The SMB coaxial jumpers used to expand the matrix with two or more Model 7072 cards need not be installed before card insertion; an access door on top of the mainframe allows access to the SMB connectors after the card is installed.

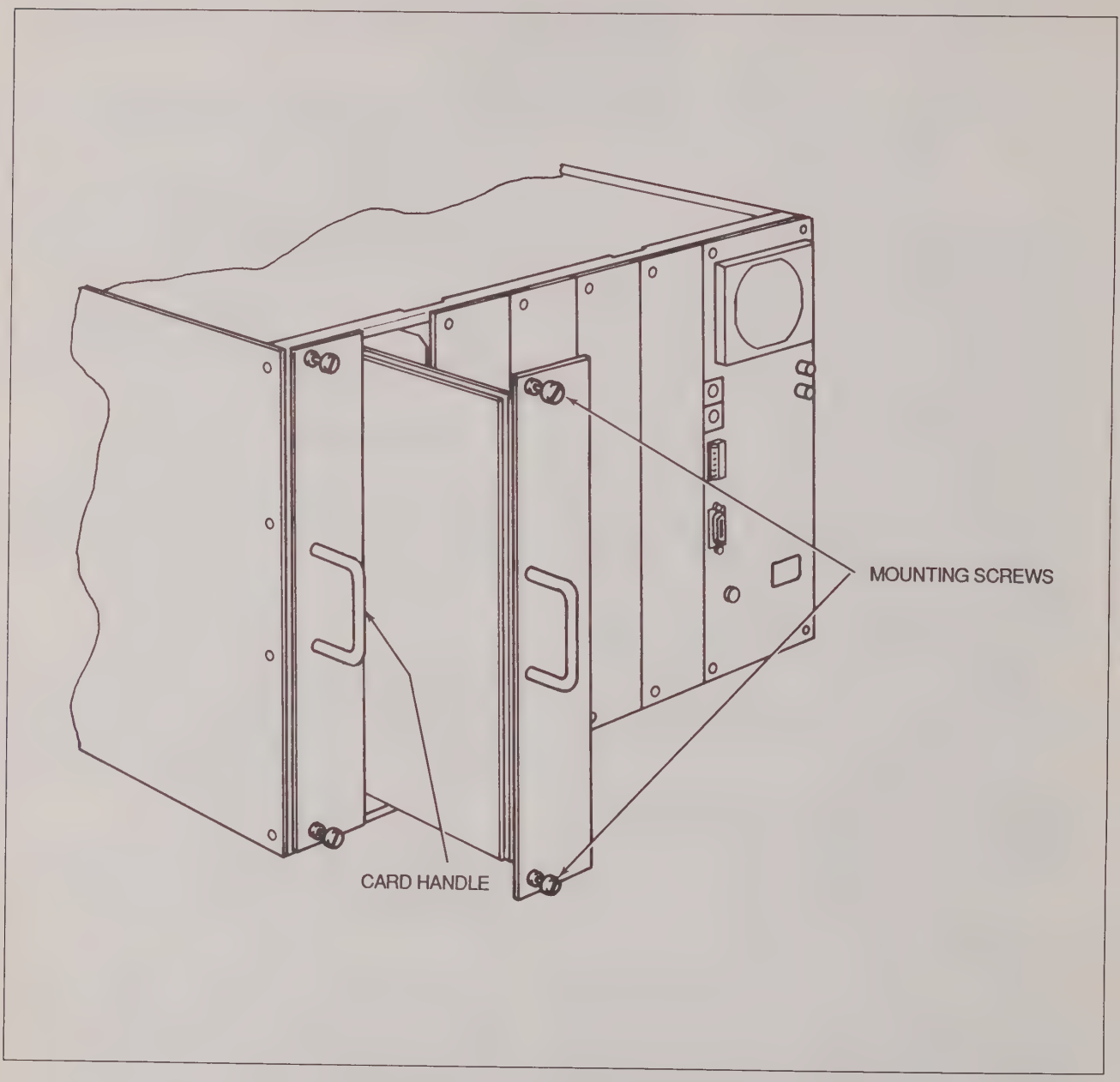


Figure 2-1. Model 7072 Installation

1. Before installing the card, make sure the access door on top of the Model 707 is fully closed and secured. The access door contains tracks for the card slots and must be in place to properly install the card.
2. With one hand grasping the handle, and the other holding the bottom of the card, line up the card with the tracks in the desired slot. Make certain that the component side of the card is facing the fan on the mainframe.

CAUTION

Do not touch the card surfaces or any components to avoid contamination that could degrade card performance.

3. Slide the card into the mainframe until it is properly seated in the edge connectors at the back of the slot. Once the card is properly seated, secure it to the mainframe by finger tightening the spring-loaded screws.

WARNING

The mounting screws must be secured to ensure a proper chassis ground connection between the card and the mainframe. Failure to properly secure this ground connection may result in personal injury or death due to electric shock.

4. To remove a card, first turn off the power and disconnect the line cord from the mainframe. Disconnect all external and internal cables (internal cables can be reached through the access door). Loosen the mounting screws, then pull the card out of the mainframe by the handle. When the back edge of the card clears the mainframe, support it by grasping the bottom edge near the back edge.

2.5 CONNECTIONS

Card connectors, recommended cables and adapters, and typical connections to test instruments are discussed in the following paragraphs.

2.5.1 Card Connectors

The card connectors are shown in Figure 2-2. Each row and column is equipped with a 3-lug female triax connector. As shown in Figure 2-3, the center conductor is SIGNAL, the inner shield is GUARD, and the outer shield, or shell is chassis ground. Note that 3-lug connectors are used to avoid possible damage from inadvertently attempting to connect BNC cables.

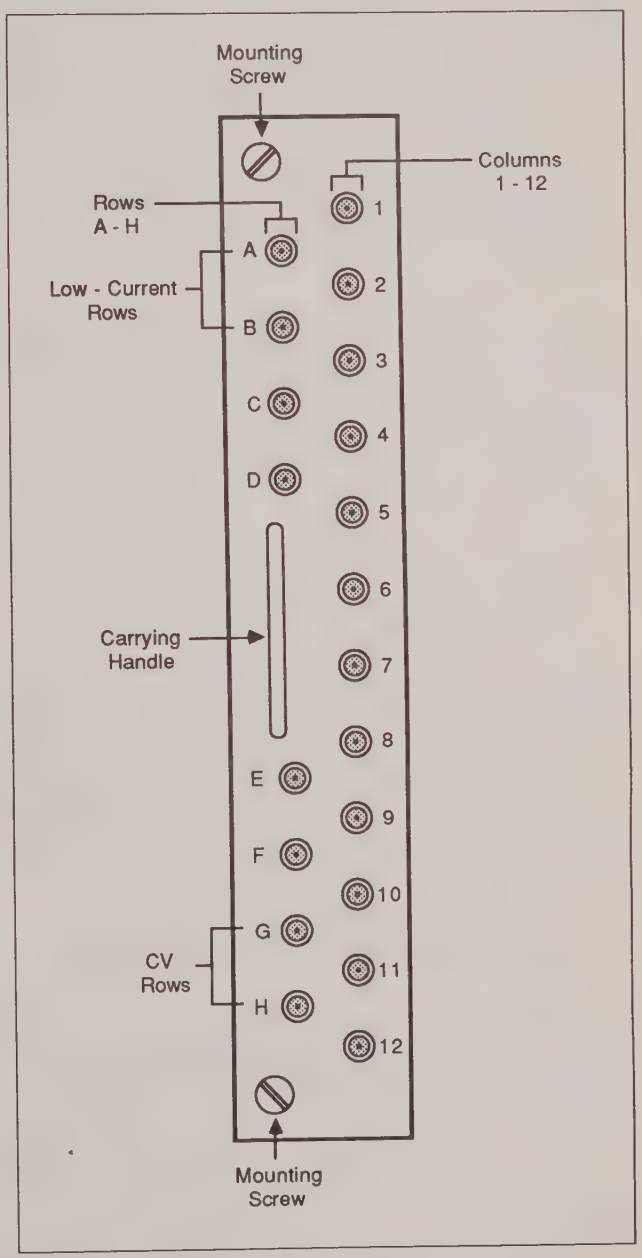


Figure 2-2. Card Connectors

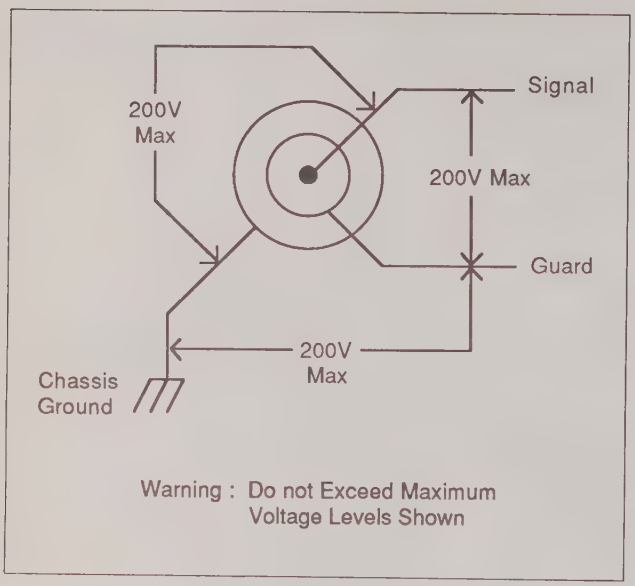


Figure 2-3. Triax Connector Configuration

WARNING
Do not exceed 200V between SIGNAL and GUARD, or between SIGNAL and chassis ground, or GUARD and chassis ground.

The Model 7072 has 12 columns that are labelled 1 through 12, as well as eight rows, A through H. Rows A and B are labelled LOW I and are intended for low-current measurements. Rows G and H are labelled CV and are designed for capacitance-voltage measurements. Rows C through F are general purpose rows that can be used for ordinary voltage, current, or resistance measurements.

2.5.2 Recommended Cables and Adapters

Table 2-1 summarizes the cables and adapters recommended for use with the Model 7072. Equivalent user-supplied items may be substituted as long as they are of sufficient quality (low offset current, high leakage resistance). Using substandard cables and adapters may degrade the integrity of the measurements made using the matrix card. See paragraph 2.7 for a discussion of measurement considerations.

Table 2-1. Recommended Cables and Adapters

Description	Applications
6171 3-slot male to 2-lug female triax.	Connect 2-slot triax cable to 7072
6011 2-slot triax to alligator cable*	7072 input/output connections
7078-TRX-3, 7078-TRX-10 triax cables	7072 input/output connections
7078-TRX-T triax tee adapter	Daisy chain 7072 columns or rows
7078-TRX-BNC triax to BNC adapter	Connect BNC cables to 7072
7025 unterminated triax (2 slot)*	For custom 7072 connections
Guarded adapter (6167**)	Guarded current source

*Model 6171 adapter required to connect these cables to Model 7072

**6167 requires modification by disconnecting input LO internally.

2.5.3 Triaxial to Banana Plug Adapter Preparation

For instruments that use banana jacks, a special 3-slot triax-to-single banana plug must be prepared, as discussed below. This special cable can be prepared as outlined below using the parts listed in Table 2-2. Note that you can use either an unterminated triax cable, or cut a dual-connector cable (7078-TRX-10) in half to construct two cables. The steps for the procedure below are shown in Figure 2-4.

1. Using a knife, cut and strip back the outer insulation about 1½ inches.
2. Remove the outer insulation, then cut away the outer shield back as far as the insulation is stripped.
3. Carefully strip away the insulation over the inner shield one inch, then cut the inner shield off even with the stripped insulation.
4. Strip the inner conductor ½ inch, then twist the strands together.
5. Unscrew the cover from a banana plug, then slide the cover over the center conductor of the triax cable.
6. Insert the stripped center conductor through the hole in the body of the banana plug, then wrap the wire around the plug body.
7. Screw on the plastic cover, and make certain the wire is secure by gently pulling on the plug.

Table 2-2. Parts for Special Triaxial Cable

Keithley Part or Model Number	Description
7078-TRX-3 triax cable*	Unterminated 3-slot triax cable
Part # B6-10-2	Red banana plug

*One connector must be cut off

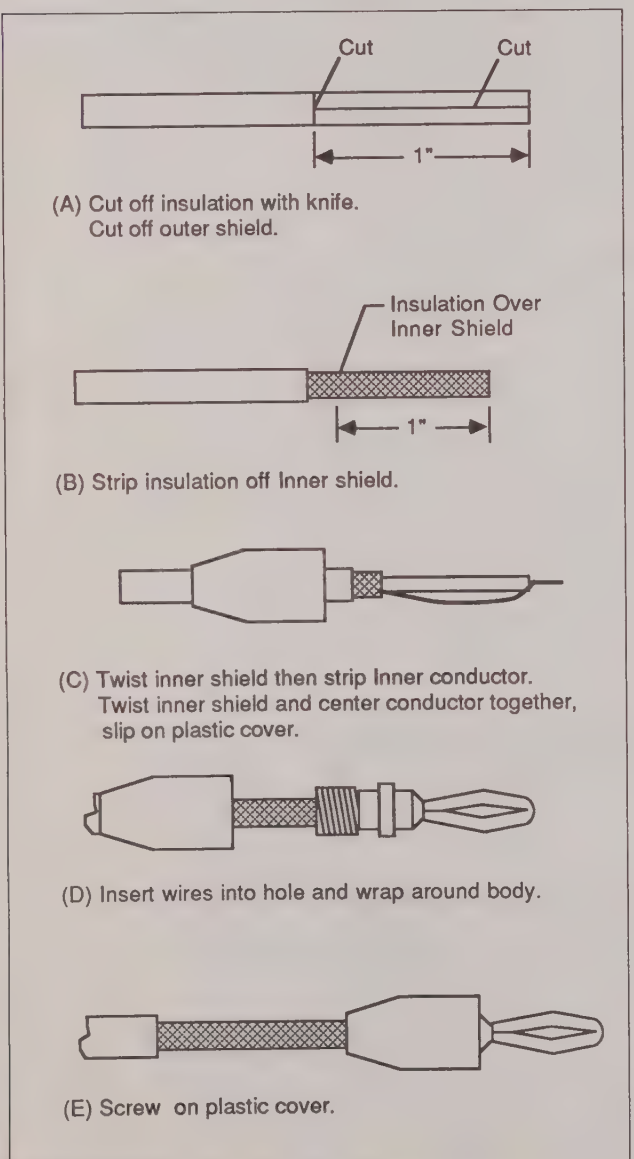

Cut
Cut
1"
(A) Cut off insulation with knife.
Cut off outer shield.
Insulation Over
Inner Shield
1"
(B) Strip insulation off Inner shield.
(C) Twist inner shield then strip Inner conductor.
Twist inner shield and center conductor together,
slip on plastic cover.
(D) Insert wires into hole and wrap around body.
(E) Screw on plastic cover.

Figure 2-4. Triaxial Cable Preparation

2.5.4 General Instrument Connections

The following paragraphs discuss connecting the Model 7072 to various general classes of instrumentation such as DMMs, electrometers, sources, and source/measure units. Because these configurations are generic in nature, some modification of the connecting schemes may be necessary for your particular instrumentation. Also, special cables or adapters may be necessary. In all cases, 3-lug triax cables must be used to make the connections.

WARNING

Do not use coaxial cables and adapters because hazardous voltage from guard sources may be present on the cable shields.

Figure 2-5 shows the general instrument connections for the discussions below. Note that DUT guarding or shielding are not indicated here; see Figures 2-21 and 2-24 for shielding and guarding information. Also, 2-pole switching for rows A-F is shown in the figures; GUARD is not switched on rows G and H. As shown, all figures assume instruments are connected to rows, and the DUT is connected to columns.

DMM Connections

General DMM connections are shown in Figure 2-5(A), (B), and (C). Floating connections are shown in (A), with LO and HI routed to two separate jacks on the Model 7072. The common LO connections in (B) should be used only for non-critical applications because the performance of the GUARD pathway is not specified.

WARNING

Hazardous voltage from other guard sources may be present on LO or the DUT if other crosspoints are closed.

4-wire DMM connections are shown in Figure 2-5(C). In this case, a total of four jacks are required; HI, LO, SENSE HI, and SENSE LO.

Electrometer Connections

Typical electrometer connections are shown in Figure 2-5(D) through (G). The unguarded volts connections in (D) show the HI signal path routed through one jack, and the LO path goes through the other connector. Both GUARD pathways are connected to electrometer LO. For guarded voltage (E), Model 7072 GUARD is connected to electrometer GUARD.

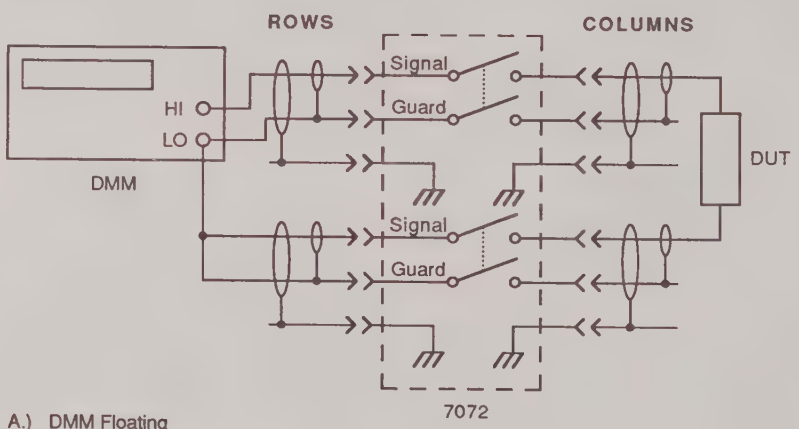
The connections for electrometer fast amps and resistance measurements are shown in Figures 2-5(F) and (G). These configurations are essentially the same as those discussed above. For the case of fast amps, both GUARD paths are connected to electrometer LO, while in the case of guarded resistance, one GUARD path is connected to electrometer GUARD, and the other GUARD path is connected to electrometer LO.

Source Connections

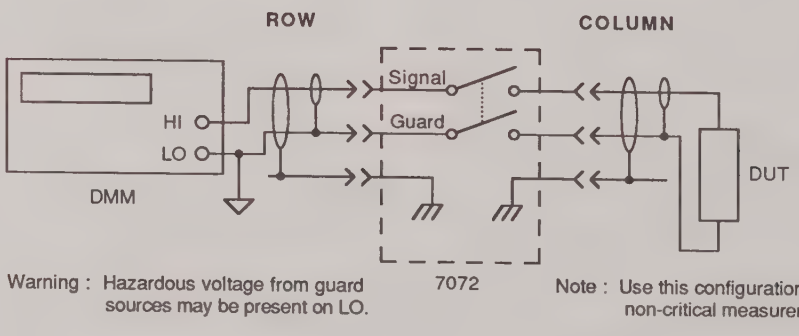
Voltage and current source connections are shown in Figures 2-5(H) through (J). The HI and LO paths of the voltage source (H) are routed through two jacks, with both card GUARD pathways connected to voltage source LO. For the unguarded current source connections (I), card GUARD is again connected to source LO, with source HI and LO routed through two pathways. In the case of the guarded current source in (J), card GUARD of the HI signal path is connected to source GUARD, and the other GUARD path is connected to source LO.

Source/Measure Unit Connections

Figure 2-5(J) shows typical connections for a source/measure unit (SMU). In this instance, a remote-sensing type of a SMU is shown, requiring a total of four signal pathways to the DUT. For critial measurements, both source and sense HI pathways would be guarded as shown, with two of the four card GUARD pathways connected to SMU GUARD terminals. As with other instrument connections, the LO card GUARD pathways are connected to SMU LO terminals.



A.) DMM Floating

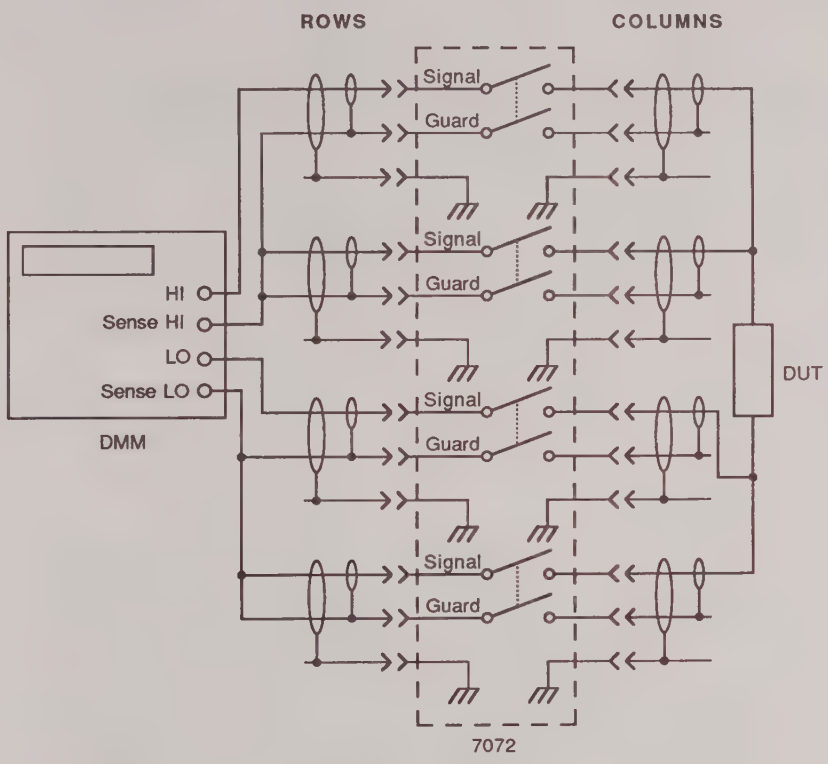


Warning : Hazardous voltage from guard sources may be present on LO.

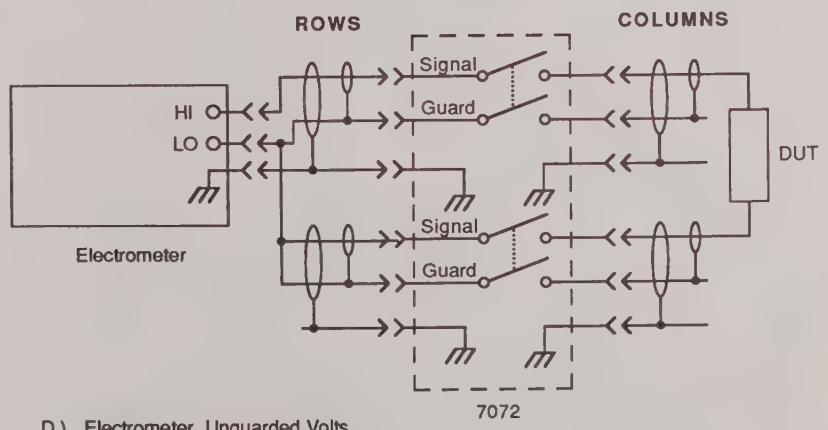
Note : Use this configuration only for non-critical measurements.

B.) DMM Common LO

Figure 2-5. General Instrument Connections (A-B)

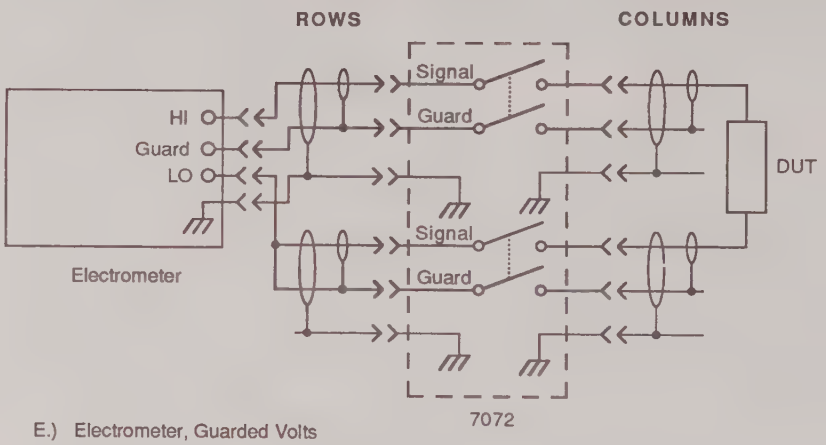


C.) DMM 4-Wire

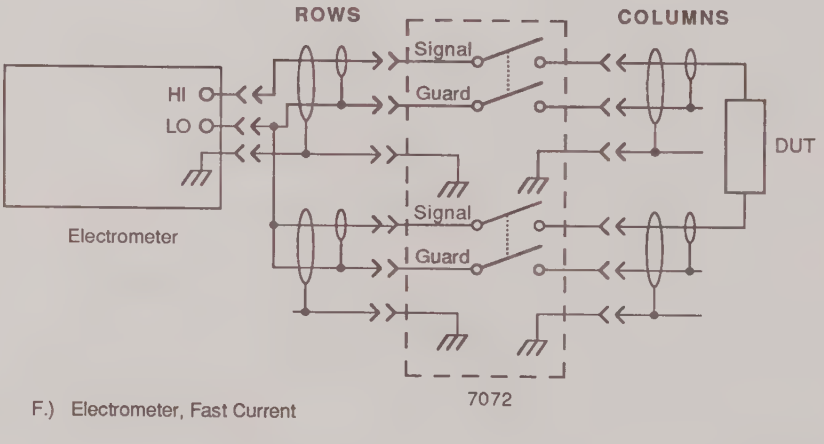


D.) Electrometer, Unguarded Volts

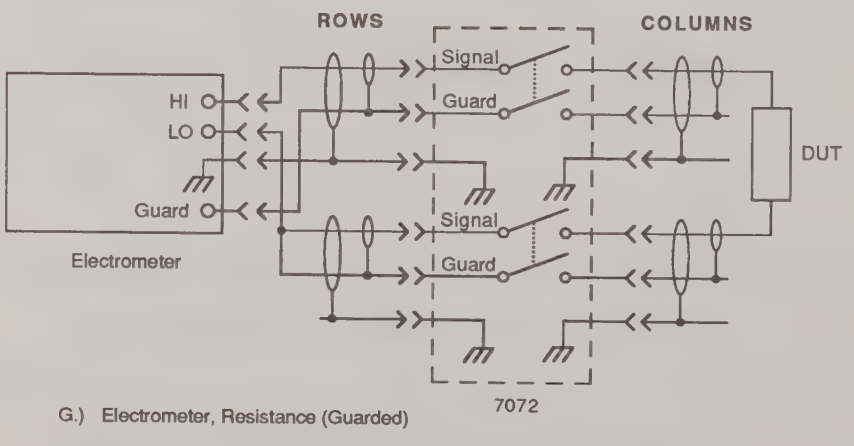
Figure 2-5. General Instrument Connections (C-D)



E.) Electrometer, Guarded Volts

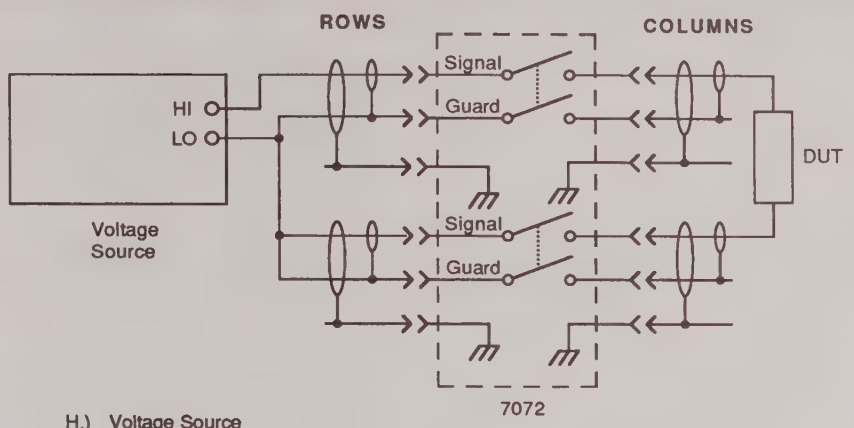


F.) Electrometer, Fast Current

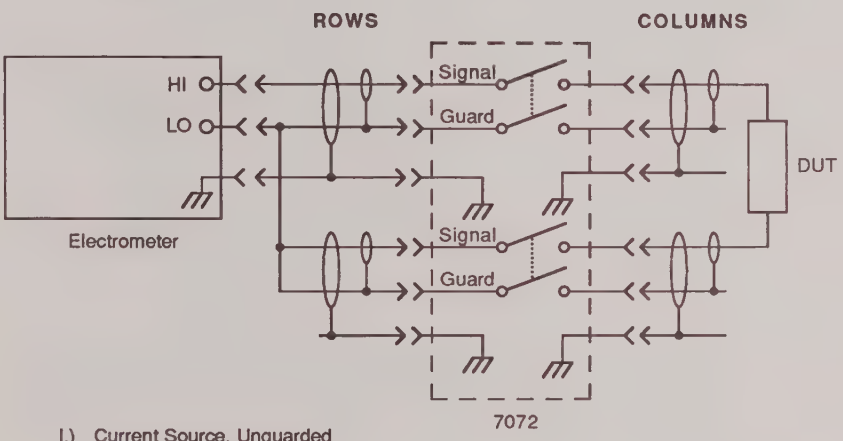


G.) Electrometer, Resistance (Guarded)

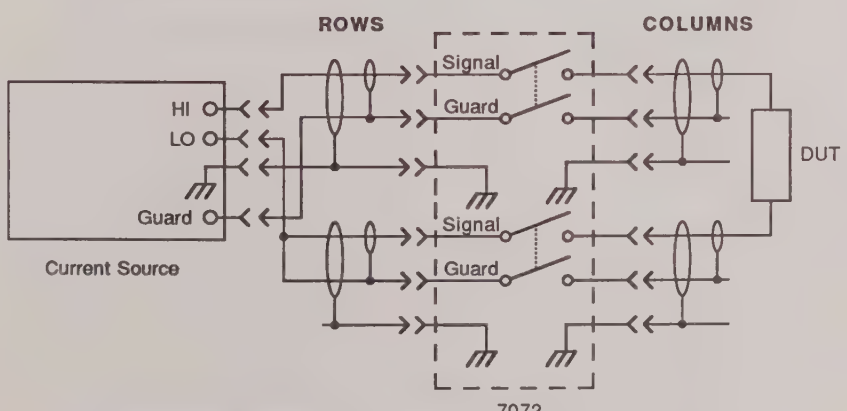
Figure 2-5. General Instrument Connections (E-G)



H.) Voltage Source

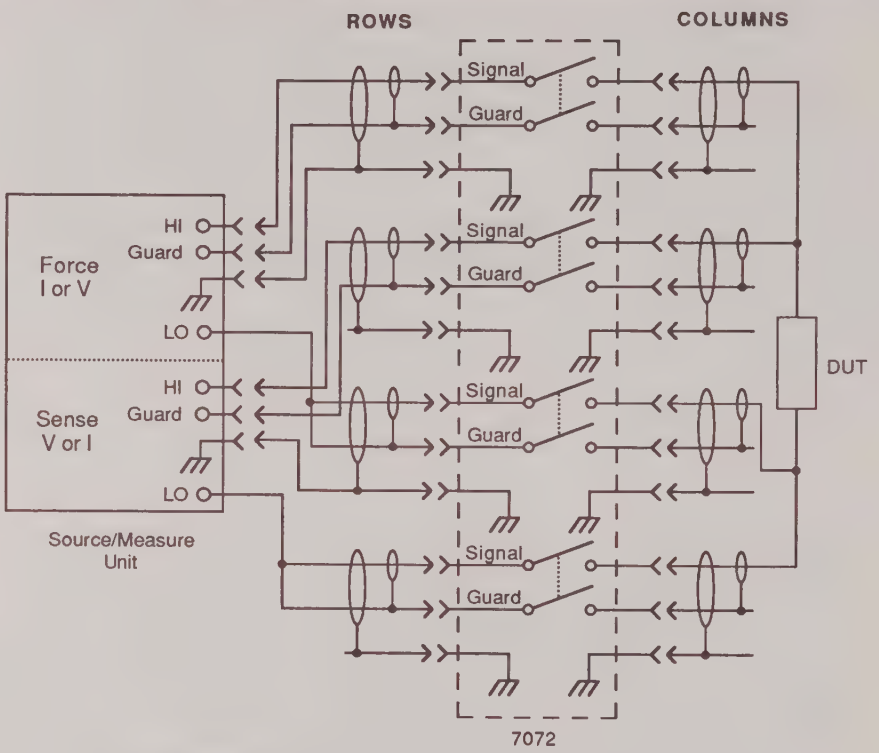


I.) Current Source, Unguarded



J.) Current Source, Guarded

Figure 2-5. General Instrument Connections (H-J)



K.) Source/Measure Unit

Notes : 1.) DUT shielding/guarding not shown. See figures 2-21 and2-24.
2.) 2-Pole switching for rows A-F shown. GUARD is not switched on rows G and H.

Figure 2-5. General Instrument Connections (K)

2.5.5 Keithley Instrument Connections

The following paragraphs outline connecting typical Keithley instruments to the Model 7072 Semiconductor Matrix Card. Other similar instruments can be connected using the same cabling as long as their input/output configurations are the same. Instrument connections covered include:

- Model 617 Electrometer/Source
- Model 196 DMM
- Model 230 Programmable Voltage Source
- Model 220 Programmable Current Source
- Model 590 CV Analyzer

Model 617 Electrometer Connections

Connections for the Model 617 Electrometer are shown in Figure 2-6. The electrometer INPUT should be connected only to rows A and B for currents less than 2nA; otherwise, current offset will affect measurement accuracy.

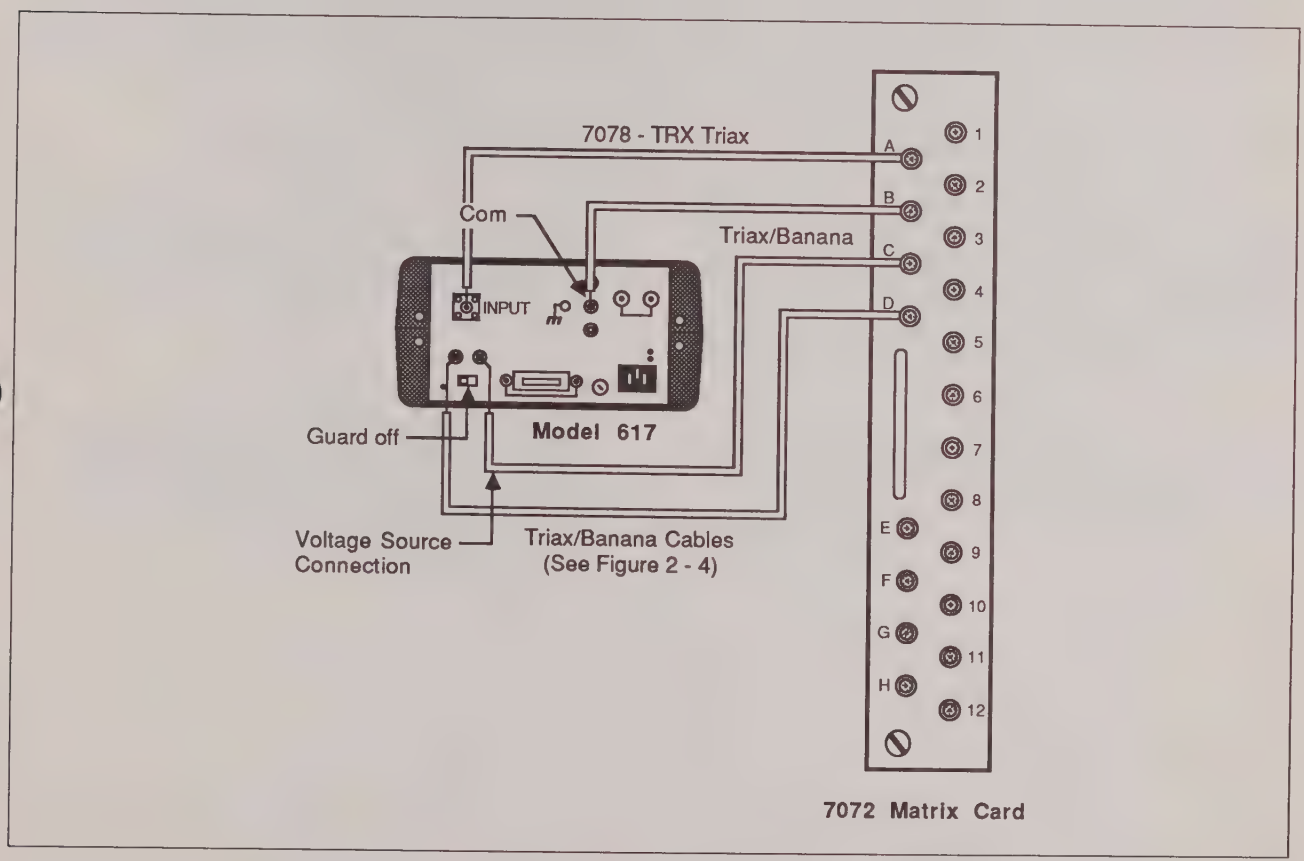


Figure 2-6. Model 617 Electrometer Connections

1. Connect one end of a Model 7078-TRX-3 or -10 3-lug triaxial cable to row A of the Model 7072.
2. Connect the other end of the triax cable to the Model 617 INPUT connector.
3. Connect the triax end of a prepared triax/banana cable to row B of the Model 7072.
4. Connect the banana plug end of the triax/banana cable to the COM terminal of the Model 617. The shorting link between COM and chassis ground should be removed for this application.
5. Place the GUARD switch in the OFF position.
6. To connect the voltage source to the Model 7072, connect the V-SOURCE HI and LO connectors of the Model 617 to the desired row connectors on the matrix card. Figure 2-6 shows connections to rows C and D.

Model 196 DMM Connections

Connect the Model 196 or other similar DMM to the matrix card using the general configuration shown in Figure 2-7. The VOLTS OHMS HI and LO terminals should be connected to the desired rows using the prepared triax/banana cables discussed above. For 4-wire ohms measurements, the OHMS SENSE HI and LO terminals should be connected to two addtional rows using the same type of cables.

NOTE

For low-level voltage measurements, connect the inner shield of the HI cable to VOLT OHMS LO to minimize noise.

Model 230 Voltage Source Connections

Connect the Model 230 OUTPUT and COMMON terminals to the desired rows using the prepared triax/banana plug cables, as shown in Figure 2-8. For remote sensing applications, the SENSE OUTPUT and SENSE COMMON connectors can be routed through two additional rows using similar cables.

Model 590 CV Analyzer Connections

The Model 590 CV Analyzer should be connected to rows G and H (CV rows), or any column as shown in Figure 2-9. The BNC cables that are supplied with the Model 590 can be used; however, Model 7078-TRX-BNC triax-to-BNC adapters must be used at the Model 7072 end.

Model 220 Current Source Connections

The Model 220 Current Source can be connected to the matrix card using the Model 6167 Guarded Adapter, as shown in Figure 2-10. This configuration guards the output signal to minimize the effects of distributed capacitance and leakage current.

NOTE

The Model 6167 Adapter must be modified by internally disconnecting the inner shield connection of the input jack from the GUARDED/UNGUARDED selection switch. Otherwise, instrument LO will be connected to chassis ground through the adapter.

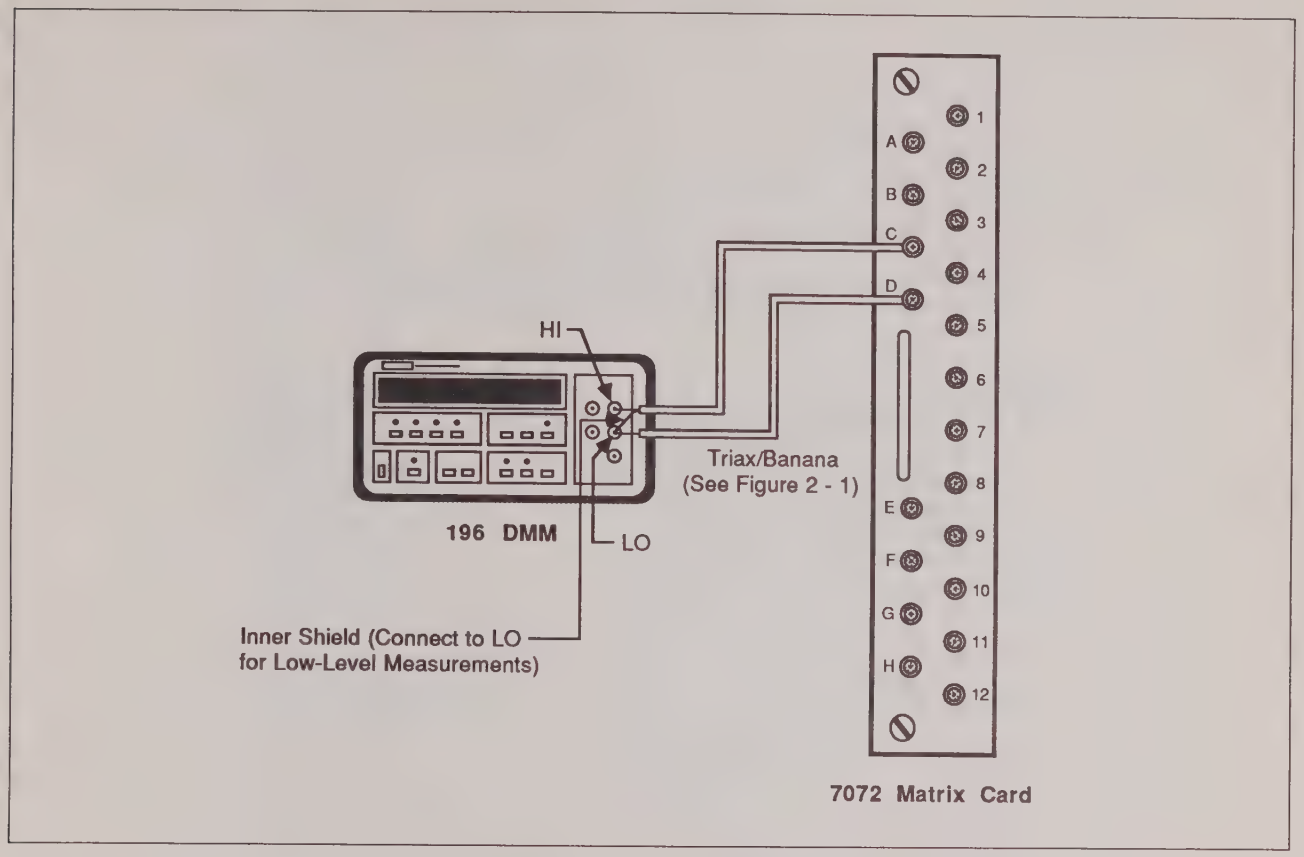


Figure 2-7. Model 196 DMM Connections

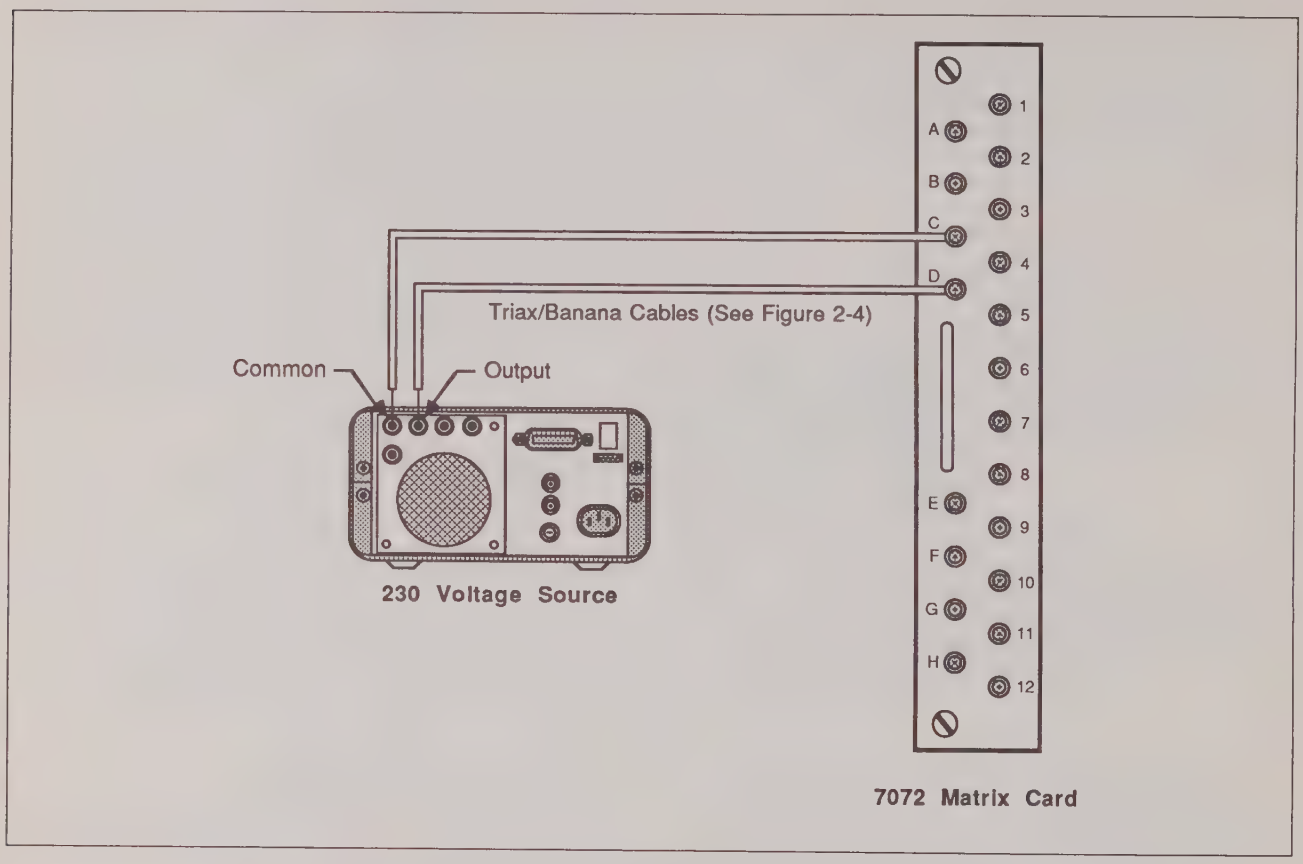


Figure 2-8. Model 230 Voltage Source Connections

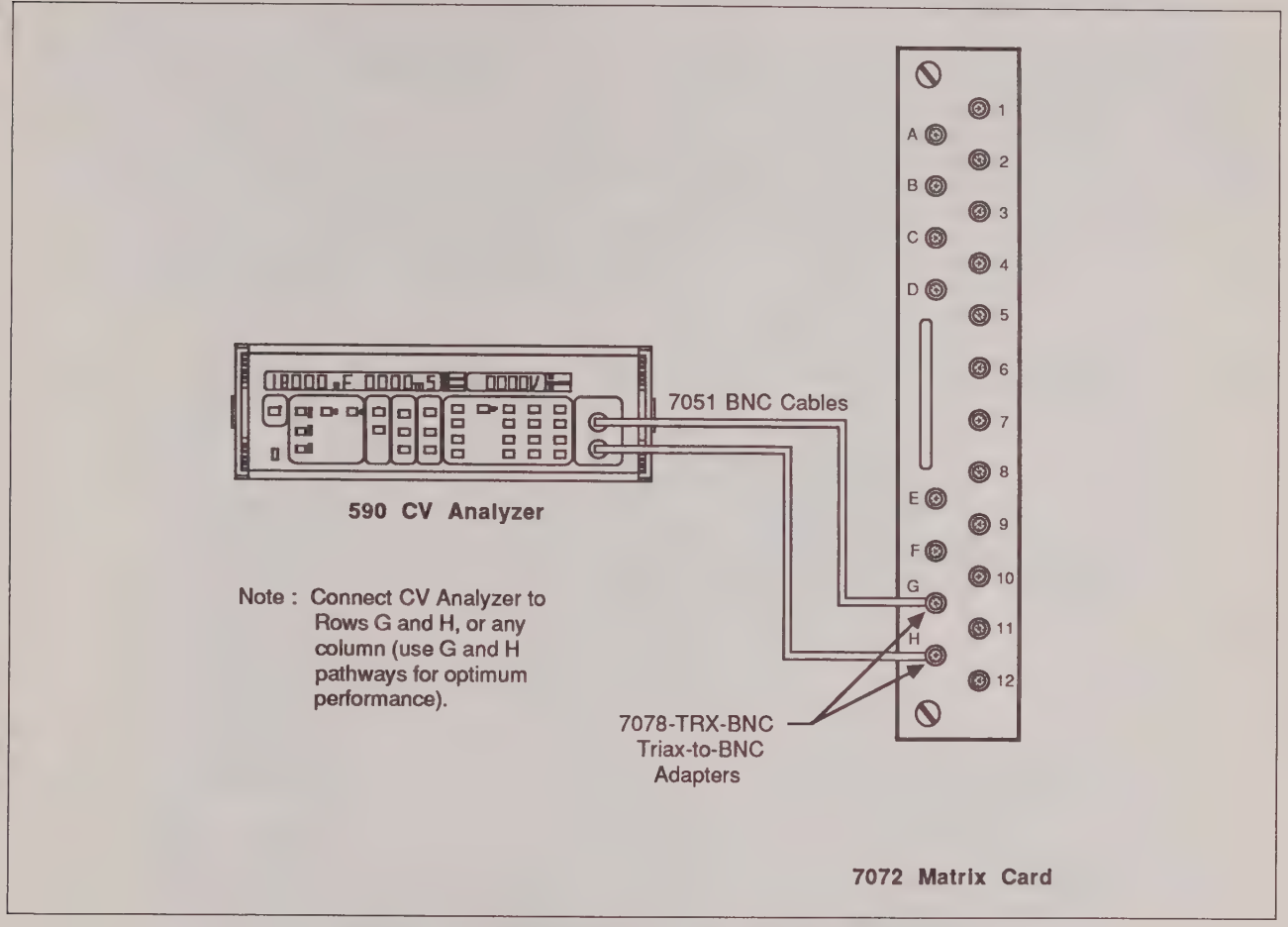


Figure 2-9. Model 590 CV Analyzer Connections

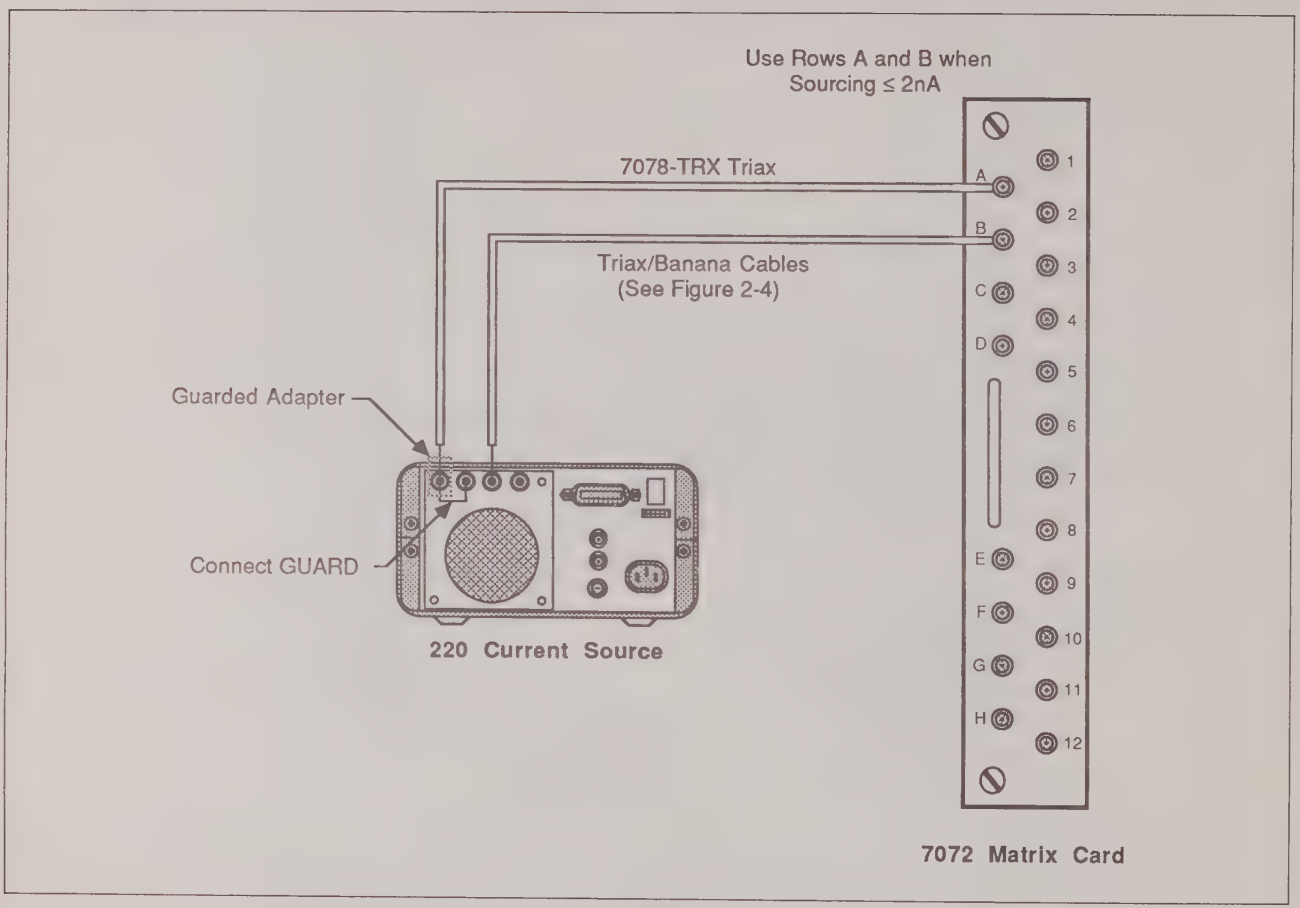


Figure 2-10. Model 220 Current Source Connections

1. Connect the Model 6167 adapter to the Model 220 OUTPUT jack.
2. Connect a Model 7078-TRX-3 or -10 triax cable between the guarded adapter and the desired row of the Model 7072.
3. Connect the Model 220 GUARD output to GUARD INPUT terminal of the adapter.
4. Connect the triax end of a triax/banana cable to the desired row on the Model 7072.
5. Connect the banana plug end of the triax/banana cable to the OUTPUT COMMON jack of the Model 220.

2.5.6 Typical Test Fixture Connections

Typically, one or more test fixtures will be connected to desired columns of the Model 7072. Typically, the test fixtures will be equipped with card-edge connectors with wires soldered to them. In some cases, the test fixture will be equipped with triax connectors; for those types, Keithley Model 7078-TRX-3 or -10 cables can be used, as shown in Figure 2-11.

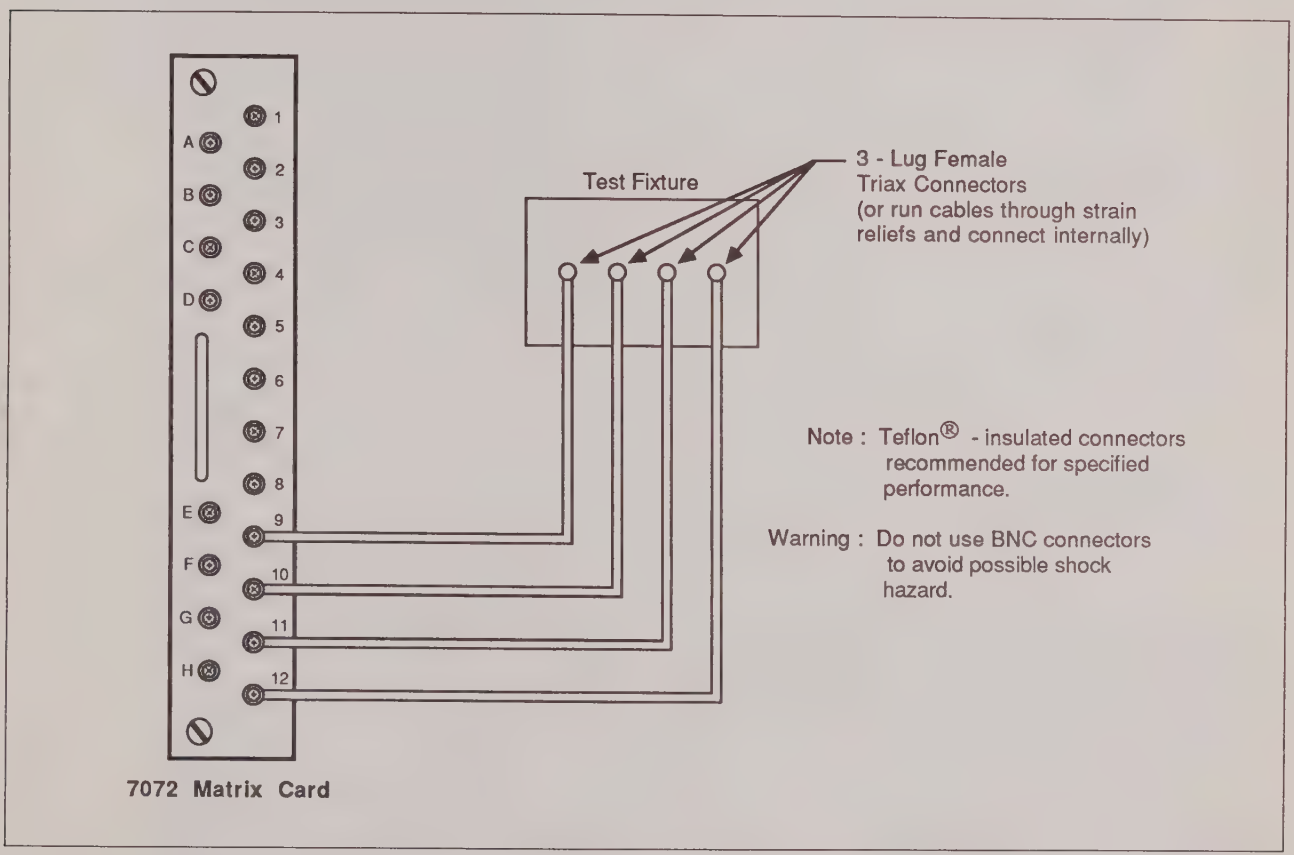


Figure 2-11. Typical Test Fixture Connections

WARNING
Do not use BNC cables and adapters in cases where hazardous voltages from guard sources could be present on the BNC cable shields.

Internally, the test fixture should be wired as shown in the equivalent circuit of Figure 2-12. SIGNAL should be connected to the probe or other device contact points, while GUARD should be carried through as close to the device as possible. If coaxial probes are to be used, connect GUARD to the probe shield if the probe shield is insulated from the fixture shield.

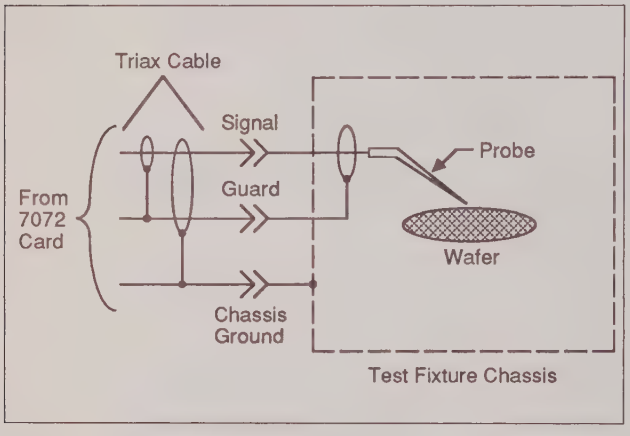


Figure 2-12. Equivalent Circuit of Test Fixture Connections

Usually, the chassis ground terminal of the triax connector will automatically make contact with the fixture shield by virtue of the mounting method. However, ground integrity should be checked to ensure continued protection against hazardous guard voltages.

2.6 MATRIX CONFIGURATION

The following paragraphs discuss the switching matrix of the Model 7072 as well as how to expand the matrix by connecting two or more cards together.

2.6.1 Switching Matrix

As shown in Figure 2-13, the Model 7072 is organized as an 8 X 12 (eight row by 12 column) matrix. The rows are labelled A through H, while the columns on the card are numbered 1 through 12. The actual column number to use when programming depends on the slot and unit number, as summarized in Table 2-3. For example, card column number 2 on a card in slot 5 of unit 1 is accessed as matrix column 62.

Table 2-3. Column Numbering by Slot and Unit

Unit	Slot	Columns (1-12)
1	1	1-12
	2	13-24
	3	25-36
	4	37-48
	5	49-60
	6	61-72
2	1	73-84
	2	85-96
	3	97-108
	4	109-120
	5	121-132
	6	133-144
3	1	145-156
	2	157-168
	3	169-180
	4	181-192
	5	193-204
	6	205-216
4	1	217-228
	2	229-240
	3	241-252
	4	253-264
	5	265-276
	6	277-288
5	1	289-300
	2	301-312
	3	313-324
	4	325-336
	5	337-348
	6	349-360

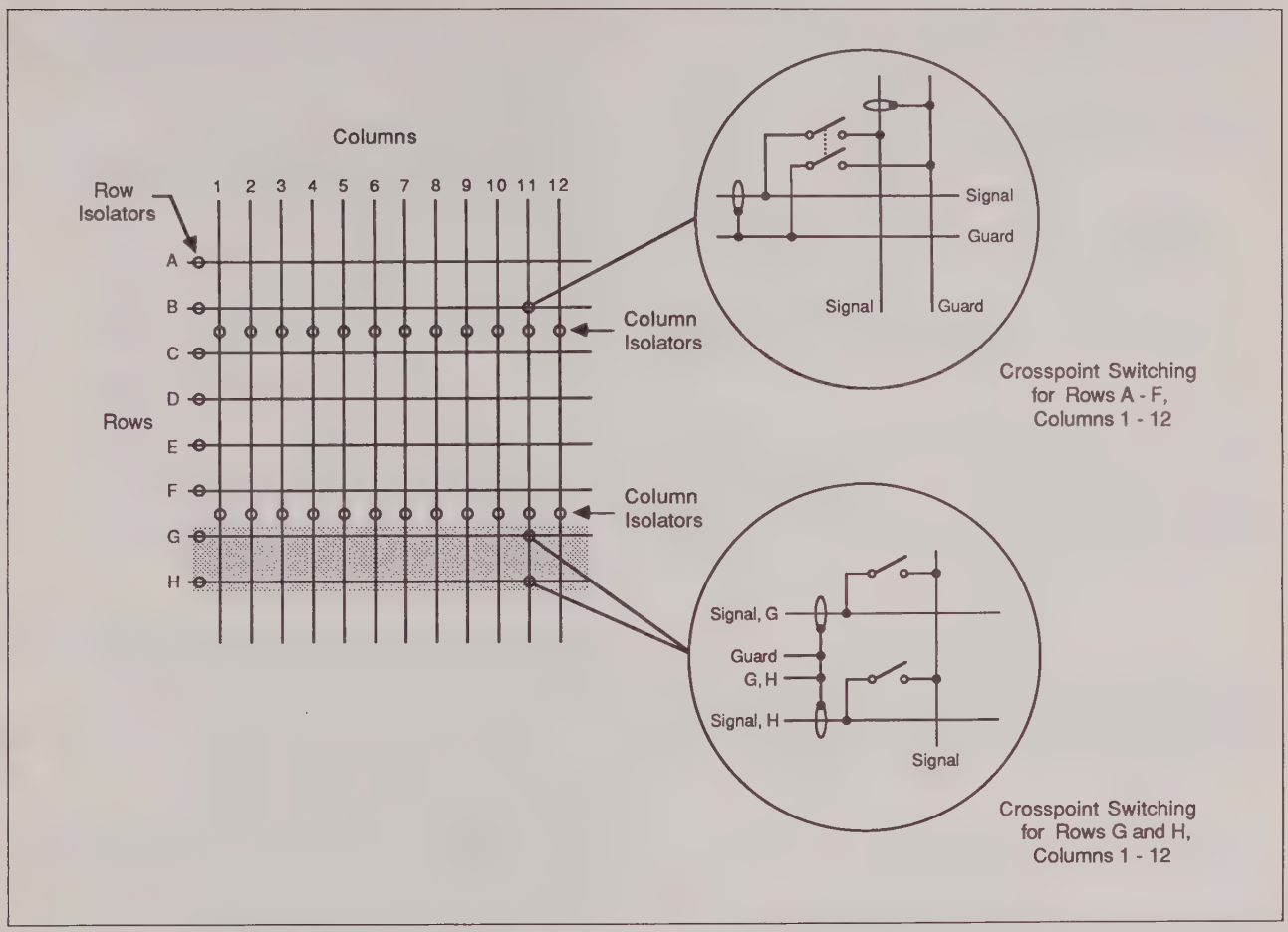


Figure 2-13. Model 7072 Matrix Organization

Each intersecting point in the matrix is called a crosspoint that can be individually closed or opened by programming the Model 707 mainframe. The crosspoints for rows A through F are configured for 2-pole switching, as shown in Figure 2-13. For these rows, SIGNAL and GUARD are switched separately to any of the 12 columns on the card.

The crosspoints for rows G and H use 1-pole switching, with only SIGNAL being switched. The equivalent circuit for this arrangement is also shown in Figure 2-13.

2.6.2 Row and Column Isolators

In order to maintain the integrity of the low-current and CV pathways, isolator relays are incorporated into each column. These isolators are indicated as small circles on the matrix diagram of Figure 2-13. Each relay remains open until a crosspoint located in rows C through H is to be closed. In this manner, the general-purpose pathways are isolated from the more critical low-current and CV pathways.

In a similar manner, row isolator relays isolate the crosspoint relays from a given row to minimize leakage current and capacitance, and maximize path resistance. The row isolator relay closes when any crosspoint relay associated with that row is closed.

2.6.3 Pathway Considerations

As discussed previously, the eight rows on the matrix card are designed for different purposes. Rows A and B are designated low-current rows, rows C through F are general purpose rows, and rows G and H are CV rows.

Many of the specifications for the card differ among row types. For example, the offset current for the low-current rows is <1pA, but the general purpose and CV rows have a higher offset current of 20pA. Thus, A and B would be the rows of choice for low-current measurements. Also, the path isolation for rows A and B is an order of magnitude higher than that the other rows ($10^{13}\Omega$ vs. $10^{12}\Omega$). Again, these two rows would be preferable for very high-impedance measurements.

In summary, the following general rules apply when choosing which rows to use for specific measurements:

- Use rows A and B for low-current measurements.
- Use rows A, B, G, and H for low-capacitance measurements.
- Rows A and B should be used where high path isolation resistance is of primary concern.
- Rows A and B have the largest bandwidth, while rows G and H have the smallest bandwidth.

For more detailed information on these factors, refer to the Model 7072 Specifications located at the front of this manual.

2.6.4 Internal Matrix Expansion

Two to six Model 7072 cards can be connected together within the mainframe to yield an 8 X N matrix, where N depends on the number of cards. Figure 2-14 shows an internally expanded matrix with three cards, resulting in an 8 × 36 (eight row by 36 column) matrix. As summarized in Table 2-3, the actual column number used when programming the unit is determined by the slot.

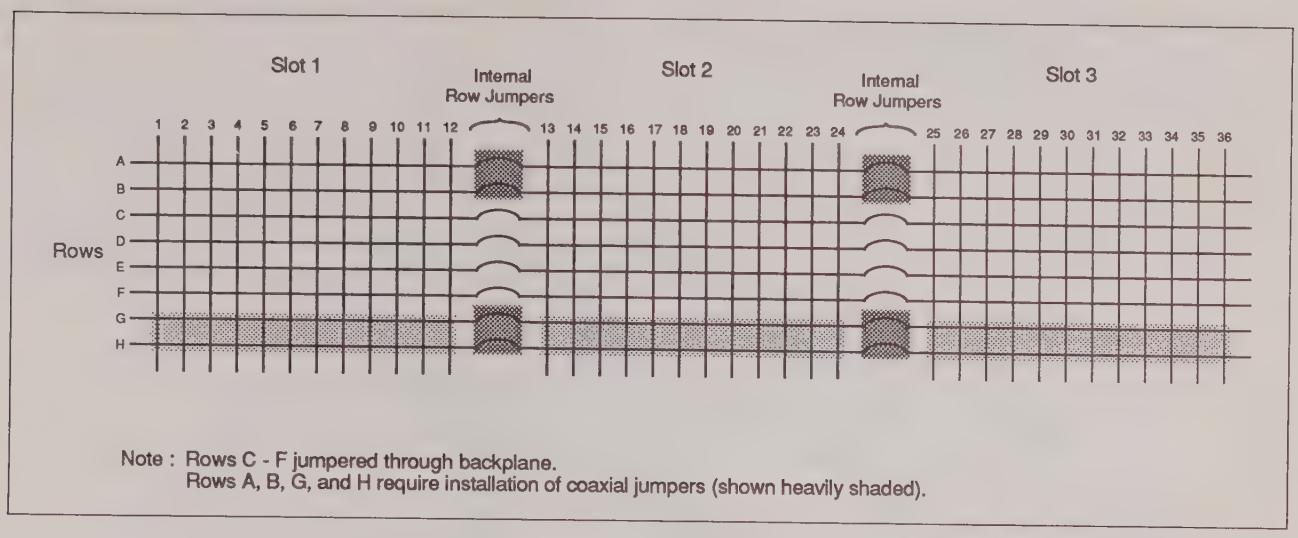

Slot 1
Internal
Row Jumpers
Slot 2
Internal
Row Jumpers
Slot 3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Rows
A
B
C
D
E
F
G
H
Note : Rows C - F jumpered through backplane.
Rows A, B, G, and H require installation of coaxial jumpers (shown heavily shaded).

Figure 2-14. Connecting Three Cards for 8 × 36 Matrix

Rows C through F are automatically connected together through the backplane of the mainframe. The mainframe can be configured for two sets of three cards each by removing jumpers from the backplane of the mainframe; see Section 3 of the Model 707 Instruction Manual for details on removing the jumpers. With the row jumpers removed, rows C through F of Model 7072 cards in slots 1 through 3 are connected, and rows C through F of Model 7072 cards in slots 4 through 6 are connected together.

Because of more critical signal paths, rows A, B, G, and H are not jumpered through the backplane. Instead, you must install the supplied coaxial jumpers between appropriate connectors on Model 7072 cards (for critical signal paths, rows can be isolated from other cards by not installing these cables). Each card has two SMB coaxial connectors for each row, allowing daisy chaining of card rows. These connectors can be reached by lifting the access door on the top of the mainframe; it is not necessary to remove cards to install the jumpers. Figure 2-15 shows an edge-on view of the jumper connectors with row numbers marked for convenience. Figure 2-16 demonstrates how three cards can be daisy chained together using the coaxial jumpers.

WARNING

The SMB coaxial shields are at guard potential. To avoid a possible shock hazard, always disconnect all cables from the row and column jacks before removing or installing jumpers.

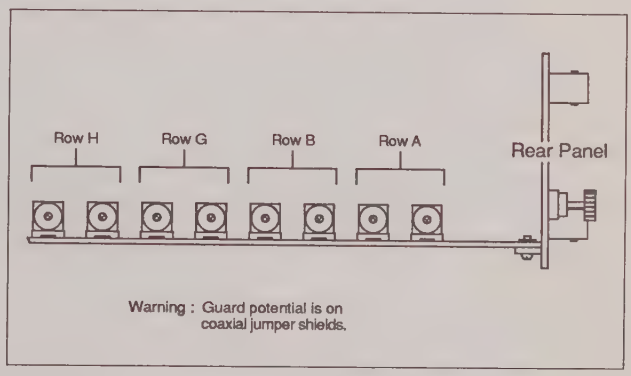


Figure 2-15. Jumper Connector Locations

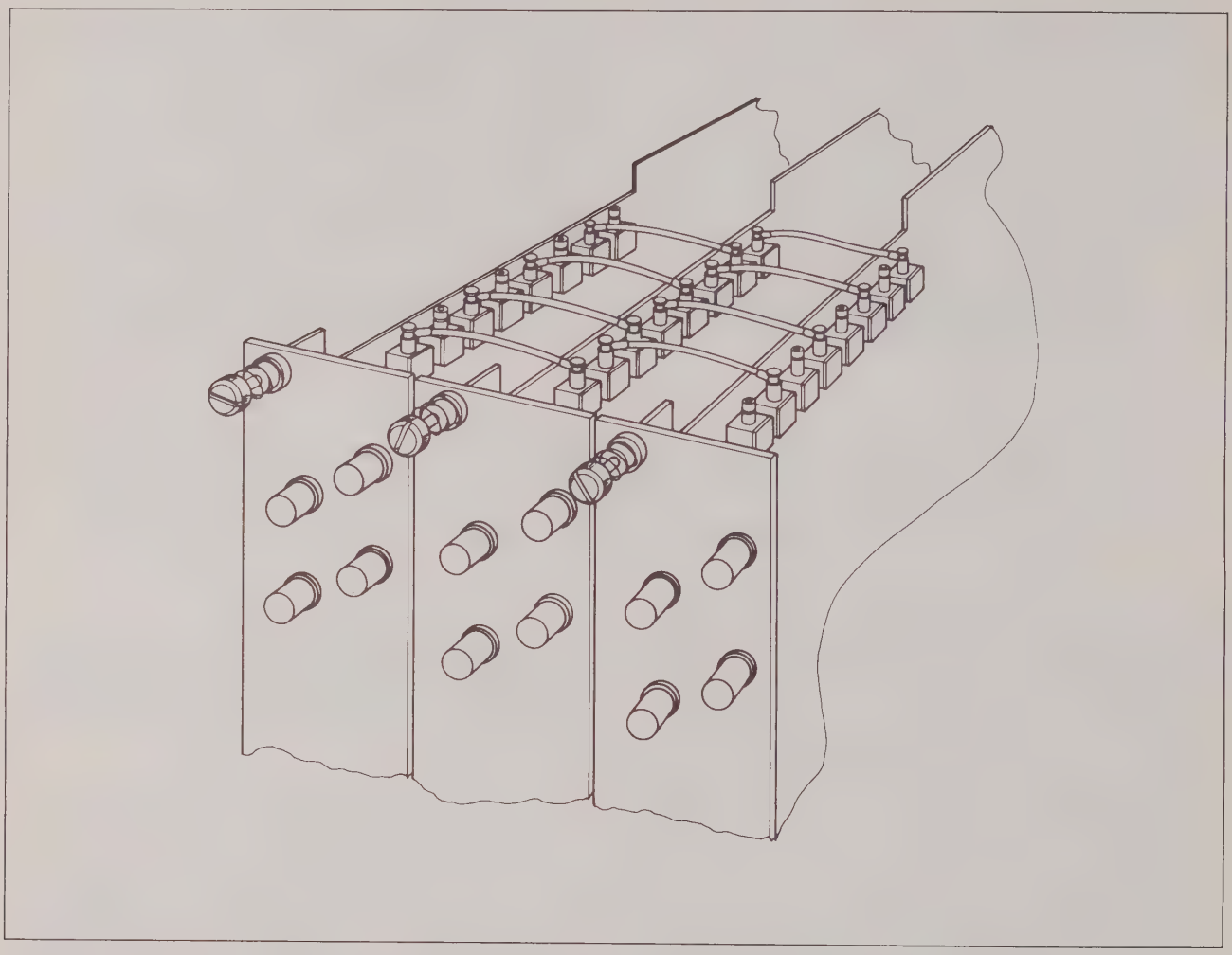
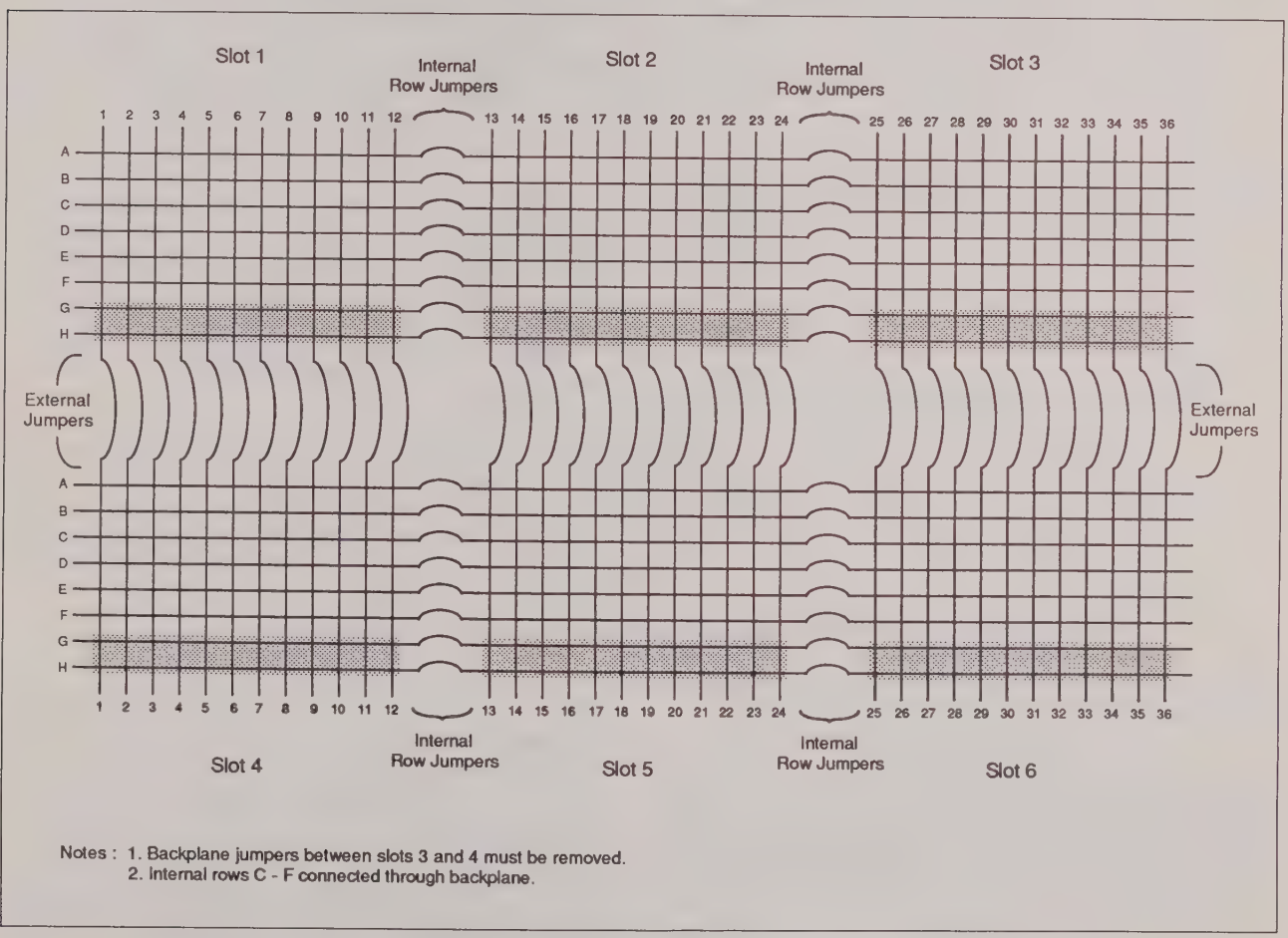


Figure 2-16. Three Cards in Daisy Chain Configuration

2.6.5 External Matrix Expansion

External jumper cables must be used to expand the number of rows in the matrix, or to connect between columns of cards installed in different mainframes. An example of such an expanded matrix is shown in Figure 2-17. Here, six cards are configured as a 16 × 36 matrix. Since the rows are internally jumpered, only columns must be jumpered externally in this configuration. Note that the backplane jumpers must be removed to separate the cards into two groups.

Triax tee adapters (Model 7078-TRX-T) can be used to provide daisy chain capability between the triax input connectors. Figure 2-18 shows a typical arrangement between two Model 7072 cards. Ideally, custom-length triax cables should be used to avoid the cable "jungle" that would occur with longer, standard-length cables.



Notes : 1. Backplane jumpers between slots 3 and 4 must be removed.
2. Internal rows C - F connected through backplane.

Figure 2-17. 16 × 36 Matrix Constructed by External Jumpering

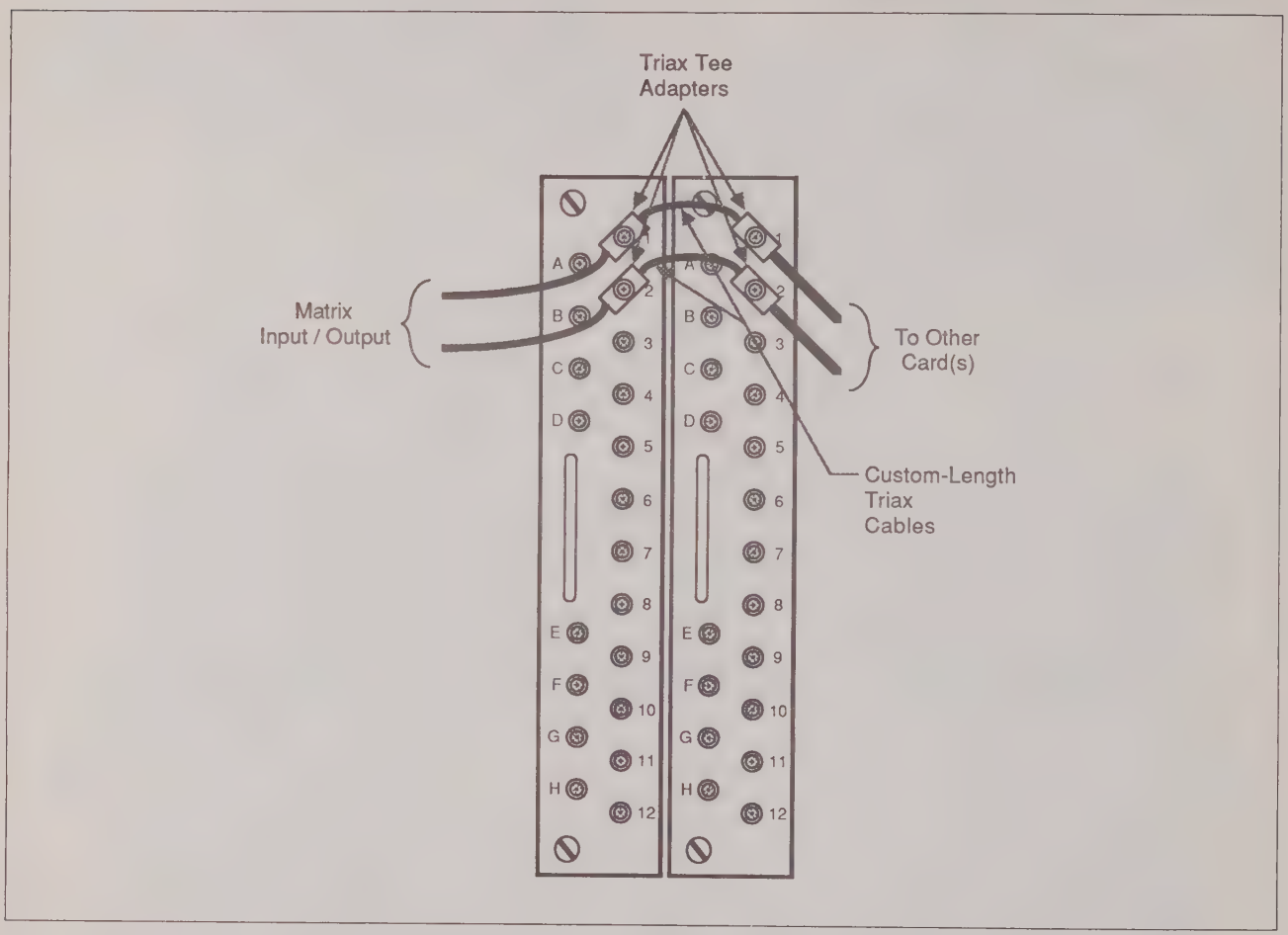


Figure 2-18. Using Triax Tee Adapters to Daisy Chain Cards

2.7 MEASUREMENT CONSIDERATIONS

Many measurements made with the Model 7072 concern low-level signals. Such measurements are subject to various types of noise that can seriously affect low-level measurement accuracy. The following paragraphs discuss possible noise sources that might affect these measurements.

2.7.1 Magnetic Fields

When a conductor cuts through magnetic lines of force, a very small current is generated. This phenomenon will frequently cause unwanted signals to occur in the test leads of a switching matrix system. If the conductor has sufficient length, even weak magnetic fields like those of the earth can create sufficient signals to affect low-level measurements.

Two ways to reduce these effects are: (1) reduce the lengths of the test leads, and (2) minimize the exposed circuit area. In extreme cases, magnetic shielding may be required. Special metal with high permeability at low flux densities (such as mu metal) are effective at reducing these effects.

Even when the conductor is stationary, magnetically-induced signals may still be a problem. Fields can be produced by various signals such as the AC power line voltage. Large inductors such as power transformers can generate substantial magnetic fields, so care must be taken to keep the switching and measuring circuits a good distance away from these potential noise sources.

2.7.2 Radio Frequency Interference

RFI (Radio Frequency Interference) is a general term used to describe electromagnetic interference over a wide range of frequencies across the spectrum. Such RFI can be particularly troublesome at low signal levels, but it can also affect measurements at high levels if the problem is of sufficient severity.

RFI can be caused by steady-state sources such as radio or TV signals, or some types of electronic equipment (microprocessors, high speed digital circuits, etc.), or it can result from impulse sources, as in the case of arcing in high-voltage environments. In either case, the effect on the measurement can be considerable if enough of the unwanted signal is present. A common problem is the rectification by semiconductor junctions of RF picked up by leads.

RFI can be minimized in several ways. The most obvious method is to keep the equipment and signal leads as far away from the RFI source as possible. Shielding the signal leads, sources, and measuring instruments will often reduce RFI to an acceptable level. In extreme cases, a specially-constructed screen room may be required to sufficiently attenuate the troublesome signal.

Many instruments incorporate internal filtering that may help to reduce RFI effects in some situations. In some cases, additional external filtering may also be required. Keep in mind, however, that filtering may have detrimental effects on the desired signal.

2.7.3 Ground Loops

When two or more instruments are connected together, care must be taken to avoid unwanted signals caused by ground loops. Ground loops usually occur when sensitive instrumention is connected to other instrumentation with more than one signal return path such as power line ground. As shown in Figure 2-19, the resulting ground loop causes current to flow through the instrument LO signal leads and then back through power line ground. This circulating current develops a small but undesirable voltage between the LO terminals of the two instruments. This voltage will be added to the source voltage, affecting the accuracy of the measurement.

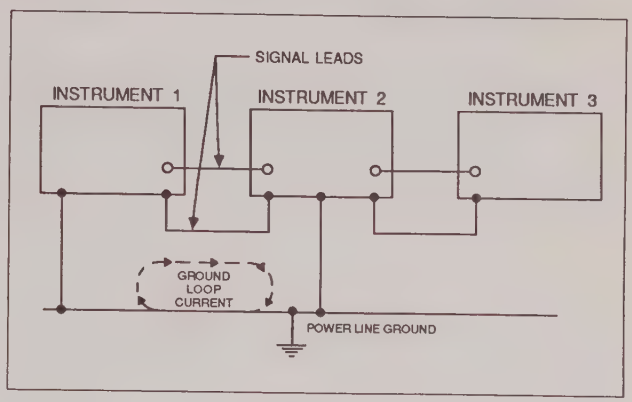


Figure 2-19. Power Line Ground Loops

Figure 2-20 shows how to connect several instruments together to eliminate this type of ground loop problem. Here, only one instrument is connected to power line ground.

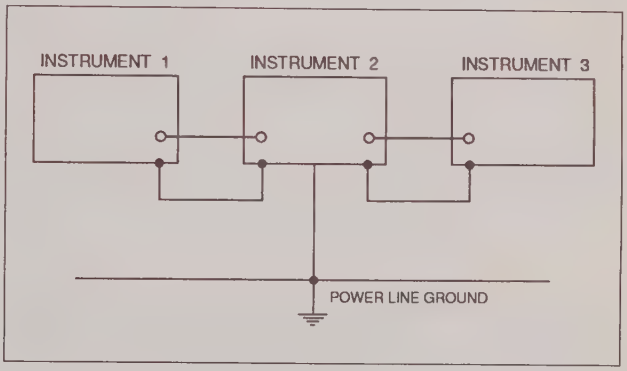


Figure 2-20. Eliminating Ground Loops

Ground loops are not normally a problem with instruments having isolated LO terminals. However, all instruments in the test setup may not be designed in this manner. When in doubt, consult the manual for all instrumentation in the test setup.

2.7.4 Keeping Connectors Clean

As is the case with any high-resistance device, the integrity of triaxial and other connectors can be damaged if they are not handled properly. If the connector insulation becomes contaminated, the insulation resistance will be substantially reduced, affecting high-impedance measurement paths.

Oils and salts from the skin can contaminate connector insulators, reducing their resistance. Also, contaminants present in the air can be deposited on the insulator surface. To avoid these problems, never touch the connector insulating material. In addition, the matrix card should be used only in clean, dry environments to avoid contamination.

If the connector insulators should become contaminated, either by inadvertent touching, or from air-borne deposits, they can be cleaned with a cotton swab dipped in clean methanol. After thorough cleaning, they should be allowed to dry for several hours in a low-humidity environment before use, or they can be dried more quickly using dry nitrogen.

2.7.5 Noise Currents Caused by Cable Flexing

Noise currents can be generated by bending or flexing coaxial or triaxial cables. Such currents, which are known as triboelectric currents, are generated by charges created between a conductor and insulator caused by friction.

Low-noise cable can be used to minimize these effects. Such cable has a special graphite coating under the shield to provide lubrication and to provide a conduction path to equalize charges.

Even low-noise cable generates some noise currents when flexed or subjected to vibration. To minimize these effects, keep the cables as short as possible, and do not subject them to temperature variations that could cause expansion or contraction. Tie down offending cables securely to avoid movement, and isolate or remove vibration sources such as motors or pumps.

2.7.6 Shielding

Proper shielding of all unguarded signal paths and devices under test is important to minimize noise pickup in virtually any switching matrix system. Otherwise, interference from such noise sources as line frequency and RF fields can seriously corrupt a measurement.

In order for shielding to be effective, the shield surrounding the HI signal path should be connected to signal LO (or chassis ground for instruments without isolated LO terminals). Since most Model 7072 matrix applications call for separately switching LO, a separate connection from LO to the cable shield at the source or measurement end must be provided, as in the example of Figure 2-21. Here, we are using the GUARD path of the Model 7072 to carry the shield out to the device under test. Needless to say, this arrangement should not be used with guarding, as GUARD and LO should not be connected together.

WARNING

Hazardous voltage may be present if LO on any instrument is floated above ground potential.

If the device under test is to be shielded, the shield should be should be connected to the LO terminal. If you are using the GUARD connection as shield, care should be taken to insulate the outer ring of the triaxial connector mounted on the test fixture from the test fixture itself. Otherwise, LO will be connected to chassis ground, possibly resulting in a ground loop. An alternative is to use two shields, one mounted within (and insulated from) the other. In this case, the GUARD path would be connected to the inner shield, while the outer shield would be chassis grounded. This arrangement is shown in Figure 2-22. Incidentally, this configuration is also recommended for guarded applications, with the inner shield as guard, and the outer shield acting as a safety shield.

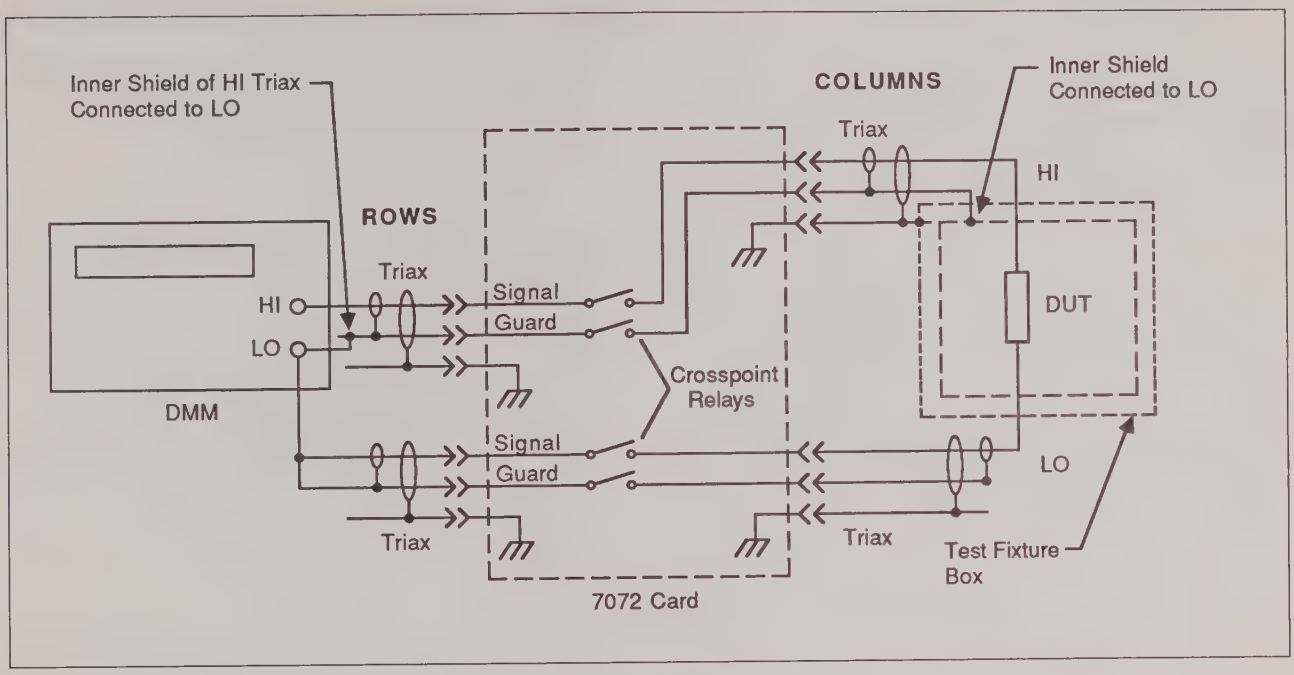


Figure 2-21. Shielding Example

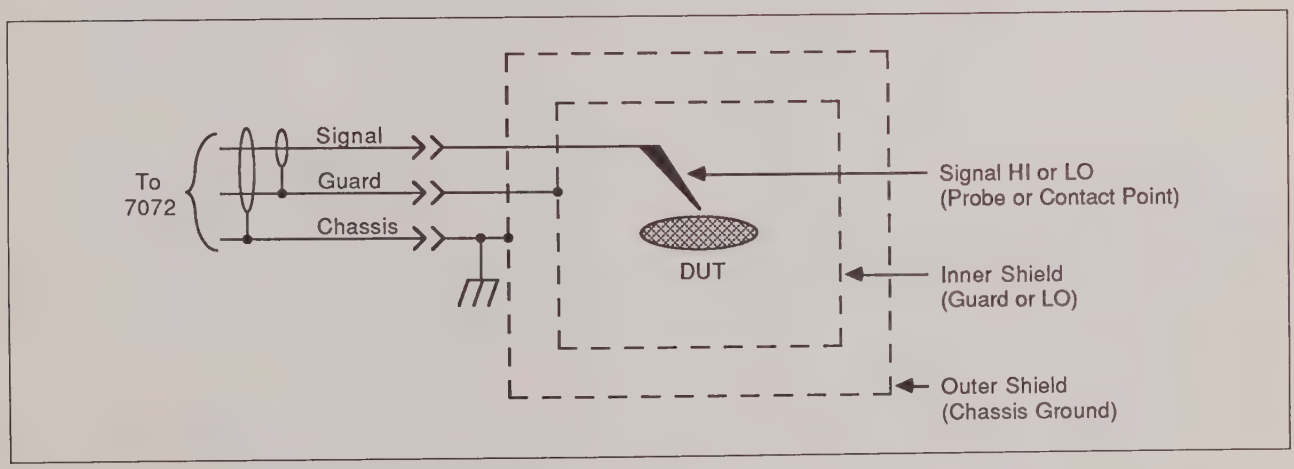


Figure 2-22. Dual Shield Test Fixture

2.7.7 Guarding

Guarding is important in high-impedance circuits where leakage resistance and capacitance could have degrading effects on the measurement. Guarding consists of using a shield surrounding a conductor that is carrying the high-impedance signal. This shield is driven by a low-impedance amplifier to maintain the shield at signal potential. For triaxial cables, the inner shield is used as guard.

Guarding minimizes leakage resistance effects by driving the cable shield with a unity gain amplifier, as shown in Figure 2-23. Since the amplifier has a high input impedance, it minimizes loading on the high-impedance signal lead. Also, the low output impedance ensures that the shield remains at signal potential, so that virtually no leakage current flows through the leakage resistance, R_L. Leakage between inner and outer shields may be considerable, but that leakage is of little consequence because that current is supplied by the buffer amplifier rather than the signal itself.

In a similar manner, guarding also reduces the effective cable capacitance, resulting in much faster measurements on high-impedance circuits. Because any distributed capacitance is charged through the low impedance of the buffer amplifier rather than by the source, settling times are shortened considerably by guarding.

In order to use guarding effectively with the Model 7072, the GUARD path of the matrix card should be connected to the guard output of the sourcing or measuring instrument. Figure 2-24 shows typical connections. Guard should be properly carried through the inner shield to the device under test to be completely effective. The shielded, guarded test fixture arrangement shown in Figure 2-22 is recommended for safety purposes (guard voltage may be hazardous with some instruments). With most instruments, special adapters or cables may be required to connect guard to the inner shield, and at the same time route signal LO through a separate cable.

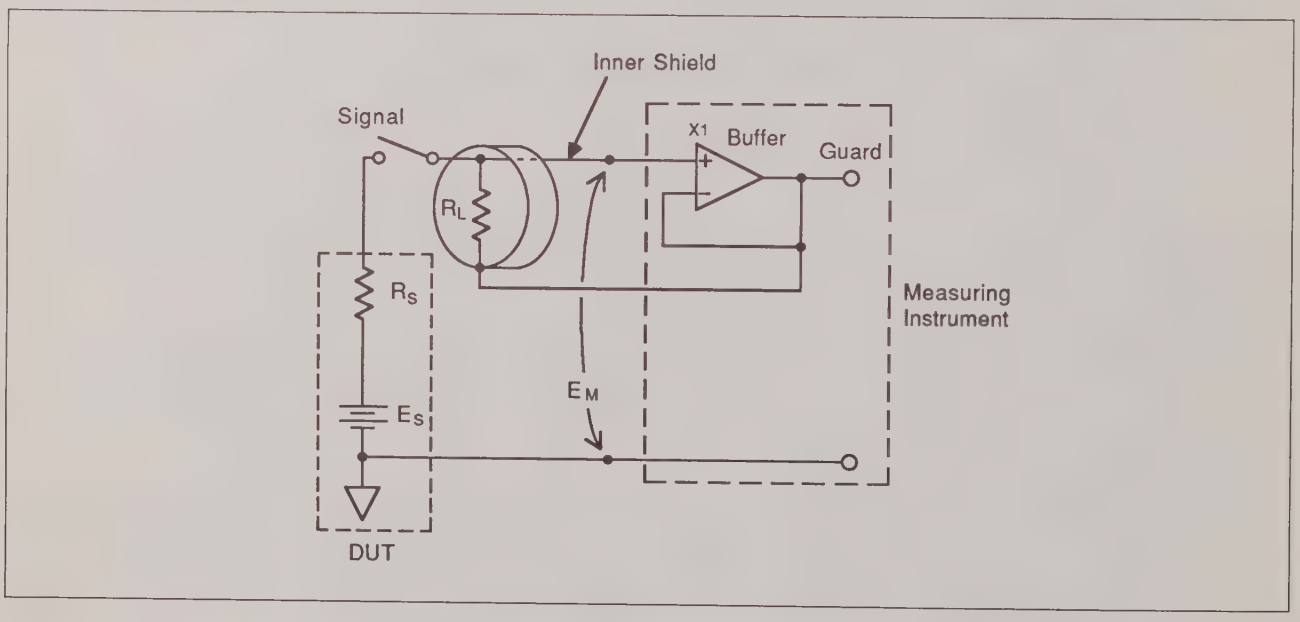


Figure 2-23. Guarded Circuit

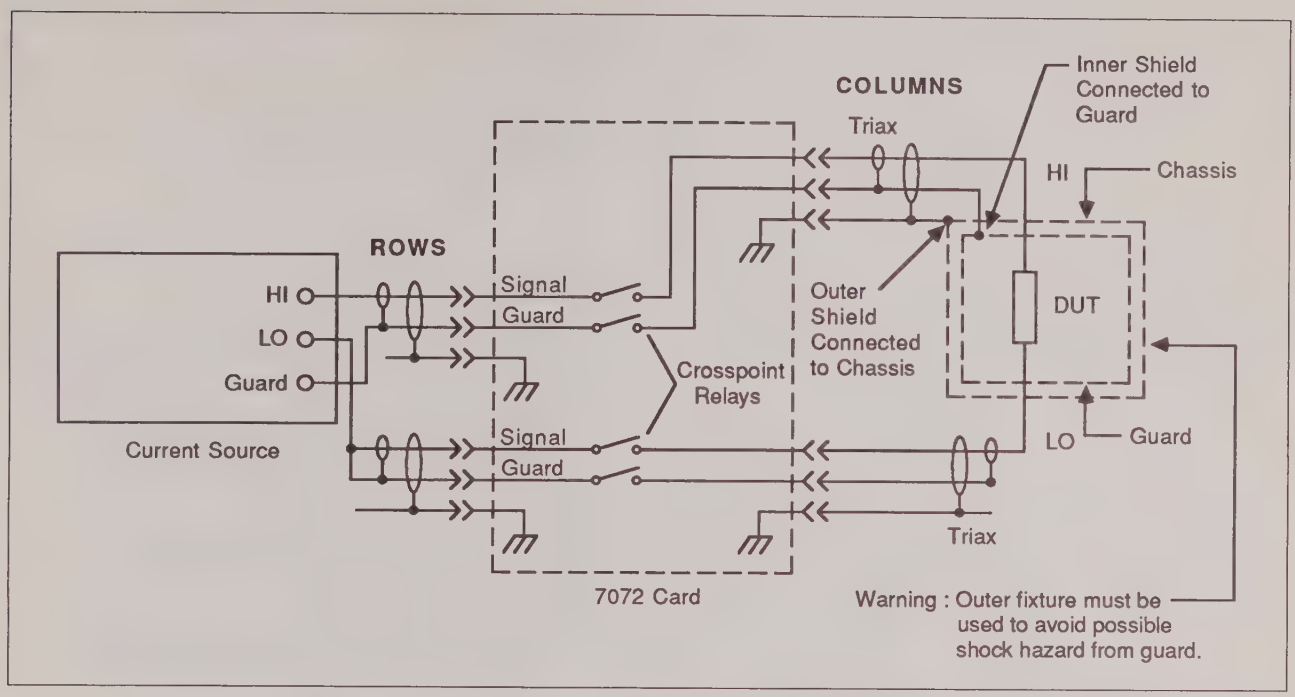


Figure 2-24. Typical Guarded Signal Connections

2.7.8 Matrix Expansion Effects on Card Specifications

Specifications such as those given for path isolation and offset current are with a single Model 7072 Card installed in the mainframe. Expanding the matrix by internally or externally connecting two or more Model 7072 Cards together will degrade system performance specifications (other types of cards do not affect the specifications because they use different pathways in the mainframe backplane). The extent depends on how many cards are used, as well as the amount of cabling used to connect them together.

With internal row expansion, isolation among rows is decreased, and offset current is increased, although the isolator relays on the card do help to minimize these effects. With external row or column expansion, isolation and offset current specifications are degraded because of the additional parallel paths and relays present on each signal line.

SECTION 3
Applications

3.1 INTRODUCTION

This section covers typical applications for the Model 7072 Semiconductor Matrix card and is organized as follows:

3.2 **CV Measurements:** Outlines the test configuration and procedure for making quasistatic and high-frequency CV measurements.

3.3 **Semiconductor Test Matrix:** Details a semiconductor test matrix that can be used to perform a variety of different tests on semiconductors such as FETs.

3.4 **Resistivity Measurements:** Covers methods to measure the resistivity of semiconductor samples using the van der Pauw method.

3.5 **Semiconductor Parameter Analysis:** Discusses using the Model 7072 in conjunction with an HP 4145B Semiconductor Parameter Analyzer.

3.2 CV MEASUREMENTS

The Model 7072 can be used in conjunction the Keithley Model 590 CV Analyzer, and the Keithley Model 595 Quasistatic CV Meter to perform quasistatic and high-frequency CV (capacitance vs. voltage) tests on semiconductors. The resulting CV curves can be used to calculate important semiconductor parameters such as doping profile, band bending, and mobile ion concentration.

3.2.1 Stand Alone System Configuration

The stand alone system shown in Figure 3-1 can be used to make CV measurements without the aid of a computer. System components perform the following functions.

Model 590 CV Analyzer: Measures CV data at 100kHz and 1MHz and sends the resulting data to the plotter for graphing.

Model 595 Quasistatic CV Meter: Measures quasistatic CV data and sends the data to the plotter for graphing in real time.

Model 707 Switching Matrix: Controls the semiconductor matrix card to close and open the desired crosspoints at the proper time.

Model 7072 Semiconductor Matrix Card: Switches the signal pathways to the six wafers under test.

HP-GL Plotter: Plots CV and other curves directly from the Models 590 and 595.

3.2.2 Computerized System Configuration

Figure 3-2 shows a computerized version of the CV matrix test system. The addition of a computer allows greater system versatility and easier instrument control. Also, analysis functions such as doping profile and ion concentration can be added to the software to expand CV analysis capabilities.

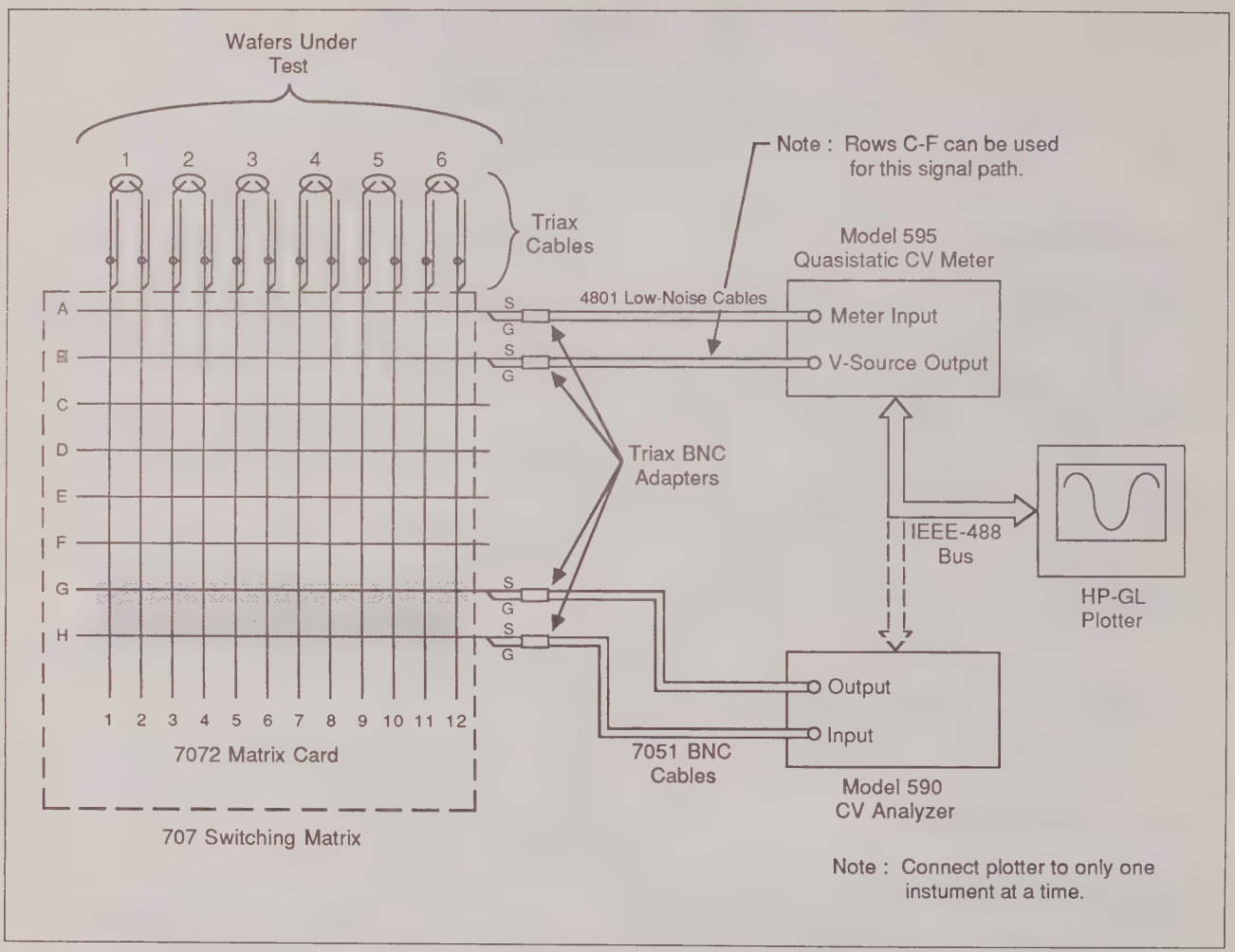


Figure 3-1. Stand Alone CV System Configuration

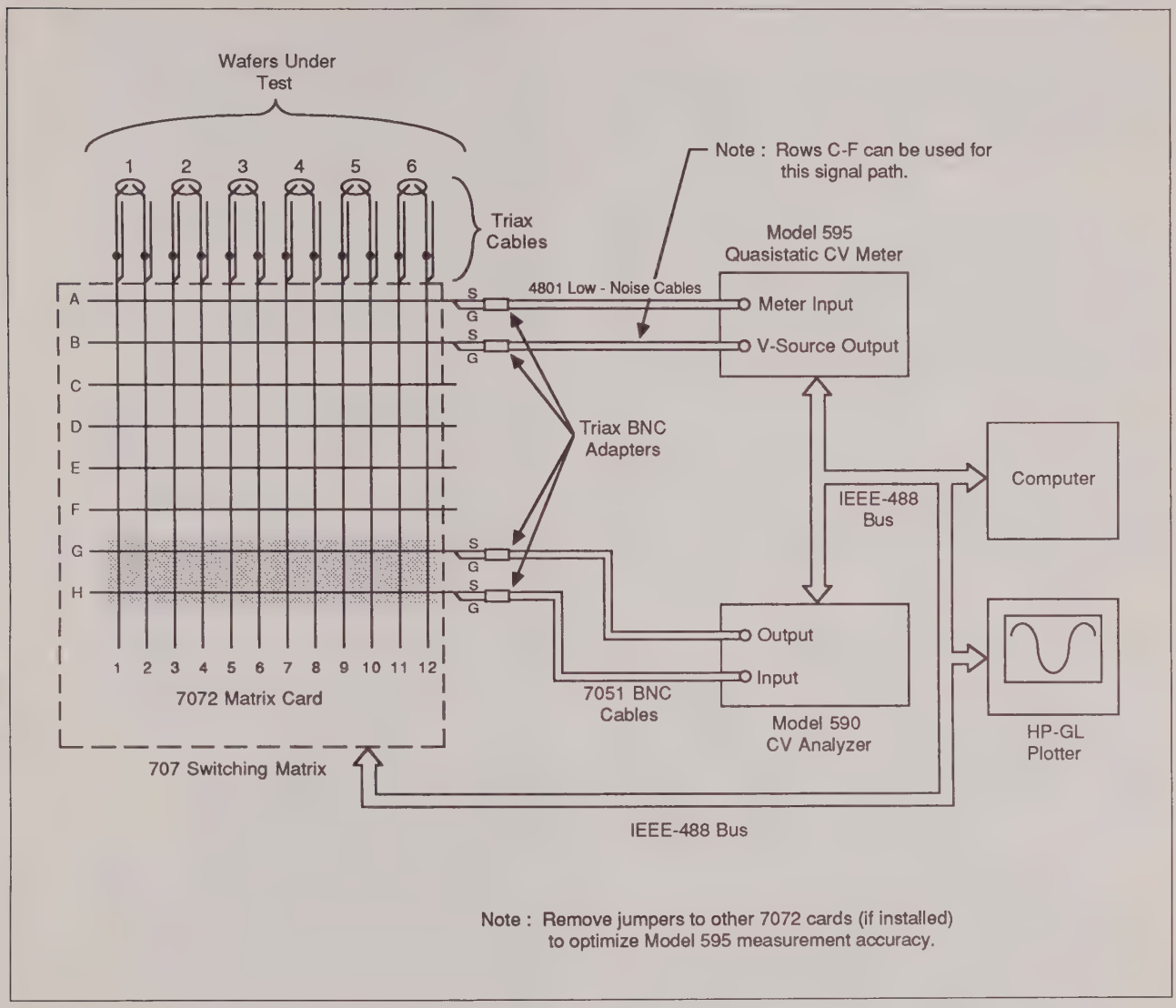


Figure 3-2. Computerized CV System Configuration

3.2.3 Optimizing CV Measurement Accuracy

For accurate CV measurements, each Model 590 CV measurement pathway must be cable corrected using the procedure outlined in the Model 590 Instruction Manual. The pathways to each DUT must be cable corrected separately.

Also, for best quasistatic CV results, the corrected capacitance feature of the Model 595 should be used. Corrected capacitance compensates for any leakage currents present in the cables, switching matrix, or test fixture. However, care must be taken when using corrected capacitance to ensure that the device remains in equilibrium throughout the test sweep to avoid distorting the CV curves.

In order to minimize the effects of the switching network on quasistatic CV measurements, cables to the Model 595 and DUT should be kept as short as possible. Also, the low-current pathways (rows A and B) should be used with the Model 595.

3.2.4 Basic CV Test Procedure

The fundamental CV test procedure is outlined below. Keep in mind that this procedure does not address many considerations and aspects of CV testing, which is fairly complex. The procedure given is for the stand alone system in Figure 3-1. Detailed instrument operating information may be found in the pertinent instruction manuals.

1. Connect the HP-GL plotter to the IEEE-488 bus connector of the Model 595 only.
2. Set up the Model 595 for the expected CV sweep.
3. Close the crosspoints necessary to connect the Model 595 to the device under test, as summarized in Table 3-1. For example, to test device #1, close A1 and B2.
4. Place the probes down on the wafer test dots.
5. Run a quasistatic sweep on the selected device and generate a CV curve.
6. Open the crosspoints that are presently closed.
7. Set up the Model 590 for the expected CV sweep.
8. Close the crosspoints necessary to connect the Model 590 to the device under test. For example, to test device #1, close G1 and H2.
9. Run a high-frequency test sweep on the device to store the CV data in the Model 590 buffer.
10. Disconnect the plotter from the Model 595 and connect it to the Model 590.
11. Generate a plot from the data in the Model 590 buffer.
12. Repeat steps 2 through 11 for the remaining devices, as required.

Table 3-1. CV Test Crosspoint Summary

Wafer #	Closed Crosspoints	
	Quasistatic (595)	High Frequency (590)
1	A1, B2	G1, H2
2	A3, B4	G3, H4
3	A5, B6	G5, H6
4	A7, B8	G7, H8
5	A9, B10	G9, H10
6	A11, B12	G11, H12

3.2.5 Typical CV Curves

Figures 3-3 and 3-4 show typical CV curves as generated by the Models 595 and 590 respectively. The quasistatic curve shows a fair amount of symmetry, while the the high-frequency curve is highly asymmetrical. The asymmetrical nature of the high-frequency curve results from the inability of the minority carriers to follow the high-frequency test signal.

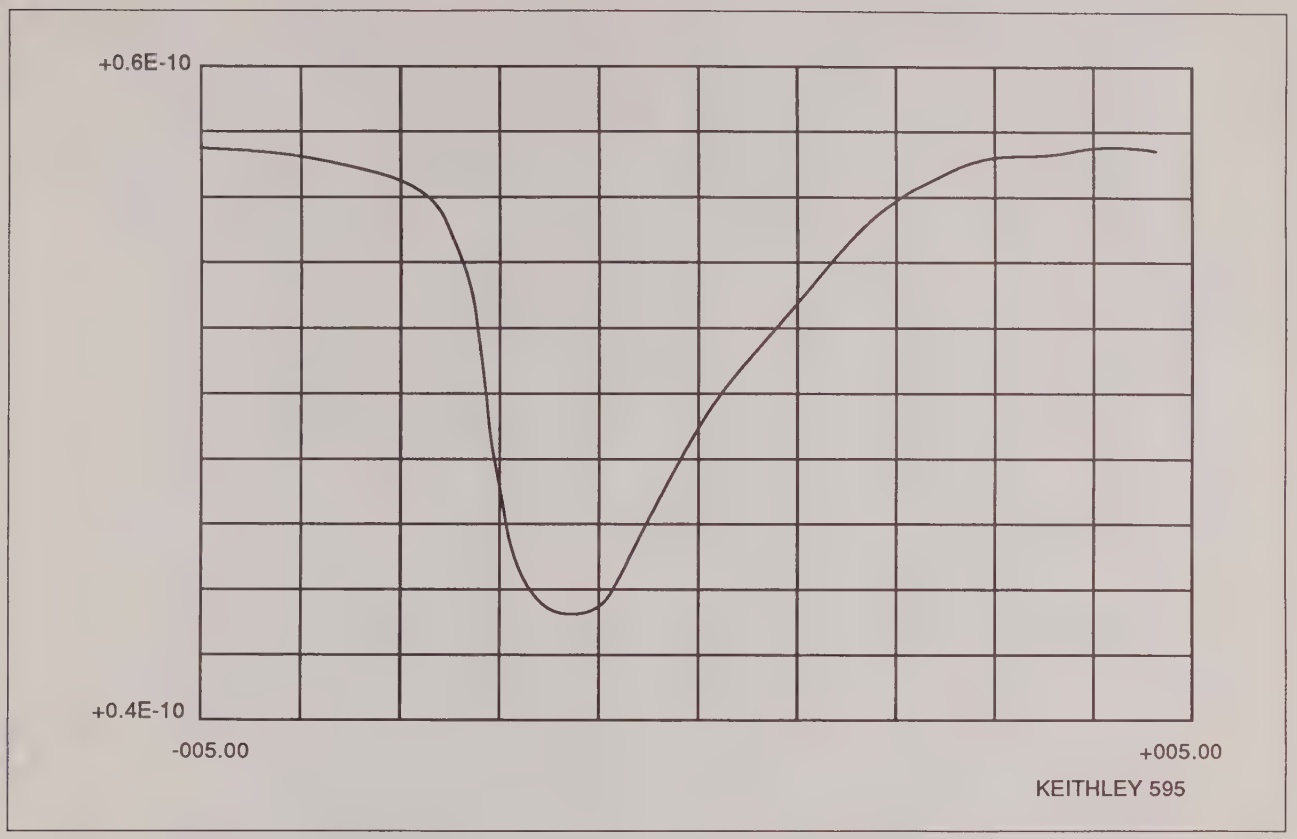


Figure 3-3. Typical Quasistatic CV Curve Generated by Model 595

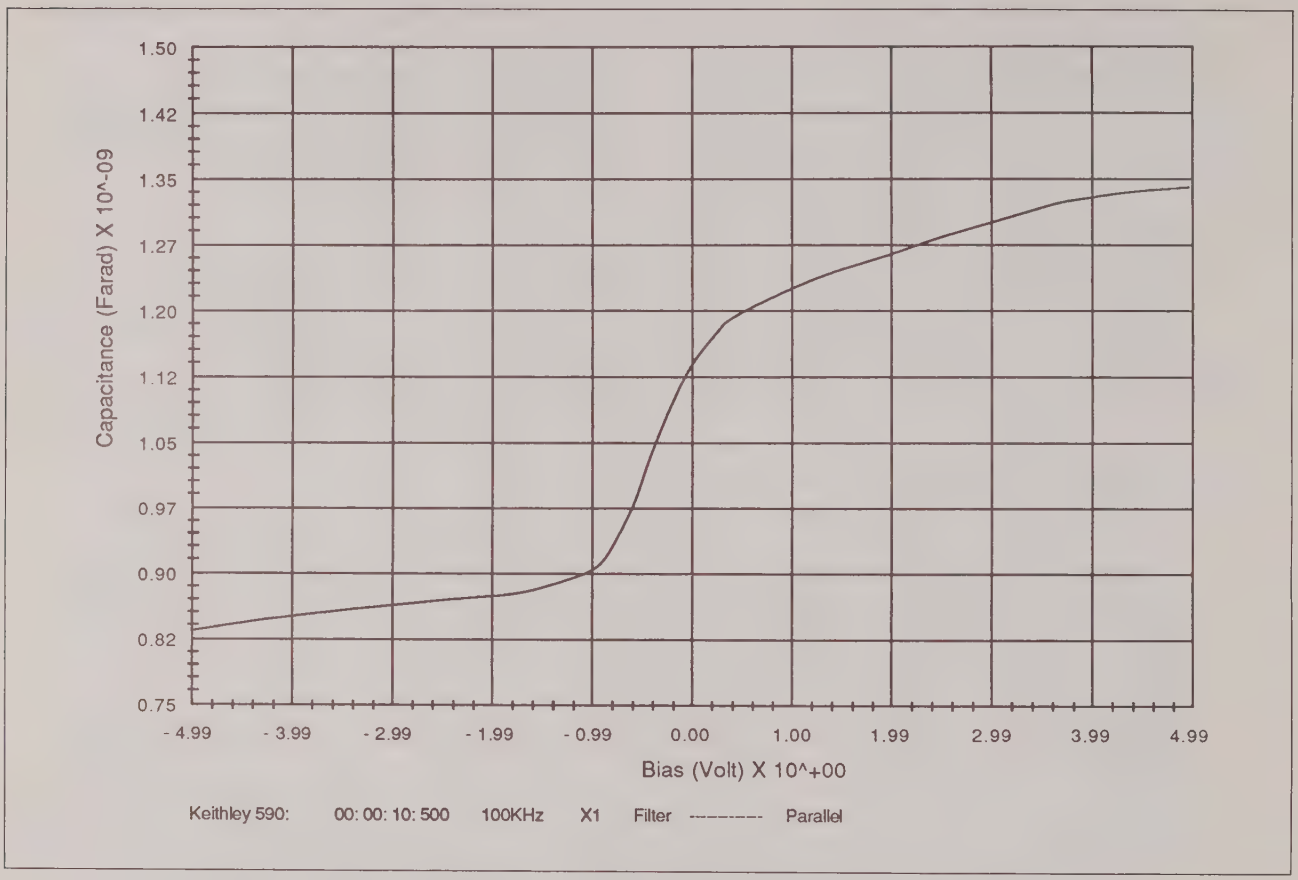


Figure 3-4. Typical High-frequency CV Curve Generated by Model 590

3.3 SEMICONDUCTOR TEST MATRIX

Two important advantages of a matrix switching system are the ability to connect a variety instruments to the device or devices under test, as well as the ability to connect any instrument terminal to any device test node. The following paragraphs discuss a typical semiconductor matrix test system and how to use that system to perform a typical test: common-source characteristic testing of a typical JFET.

3.3.1 System Configuration

Figure 3-5 shows the configuration for a typical multipurpose semiconductor test matrix. Instruments in the system perform the following functions.

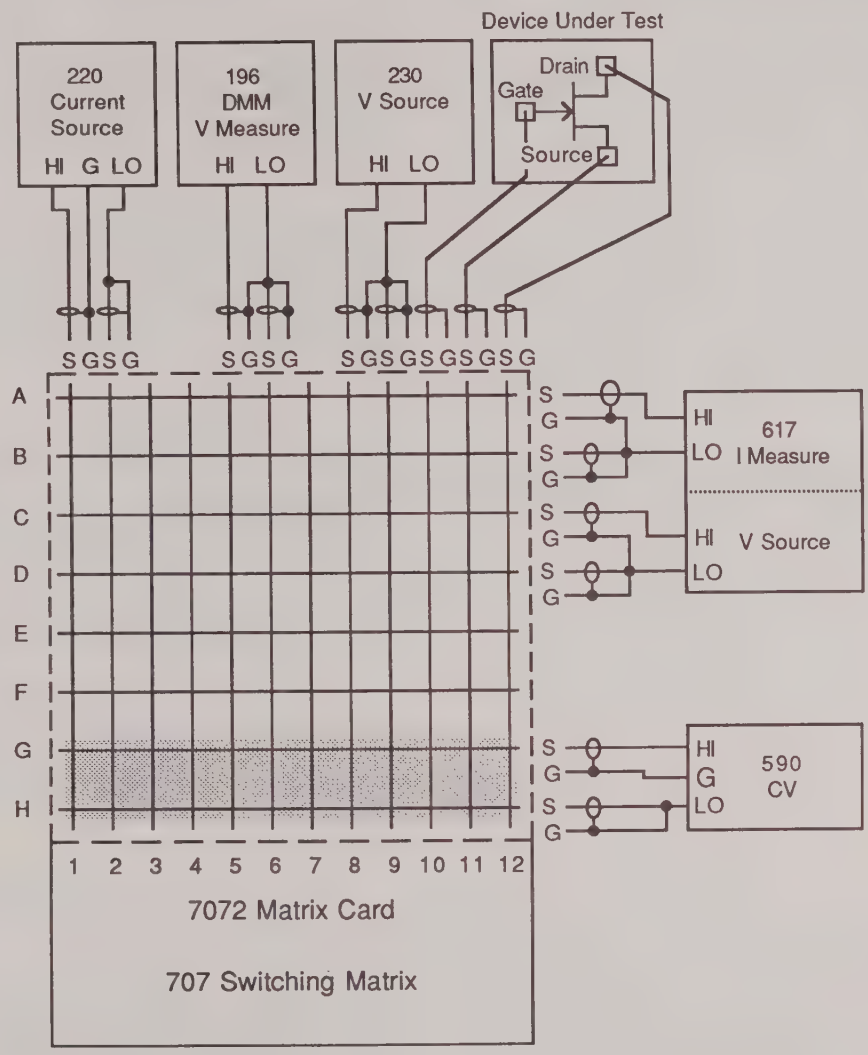


Figure 3-5. Semiconductor Test Matrix

Model 617 Electrometer/Source: Measures current, and also could be used to measure voltages up to ±200VDC. The DC voltage source can supply a maximum of ±100V at currents up to 2mA.

Model 230 Voltage Source: Sources DC voltages up to ±101V at a maximum current of 100mA.

Model 590 CV Analyzer: Adds CV sweep measurement capability to the system.

Model 220 Current Source: Used to source currents up to a maximum of 101mA with a maximum compliance voltage of 105V.

Model 196 DMM: Measure DC voltages in the range of 100nV to 300V. The Model 196 could also be used to measure resistance in certain applications.

Device Under Test: A three-terminal fixture for testing such devices as bipolar transistors and FETs. Additional connections could easily be added to test more complex devices, as required.

3.3.2 Testing Common-Source Characteristic of FETs

The system shown in Figure 3-5 could be used to test a variety of characteristics including I_{GSS}, $I_{D[OFF]}$, $I_{G[ON]}$, I_{DSS}, and $V_{DS[OFF]}$. To demonstrate a practical use for the system, we will show how it can be used to generate common source characteristic curves of a particular JFET.

In order to generate these curves, the instruments must be connected to the JFET under test, as shown in Figure 3-6. The advantage of using the matrix is, of course, that it is a simple matter of closing specific crosspoints. The crosspoints that must be closed are also indicated on the diagram.

To run the test, V_{GS} is set to specific specific values, for example in increments of 0.25V. At each V_{GS} value, the drain-source voltage (V_{DS}) is stepped across the desired range, and the drain current, I_D, is measured at each value of V_{DS} . Once all data are compiled, it is a simple matter to generate the common-source IV curves, an example of which is shown in Figure 3-7. If the system is connected to a computer, the test and graphing could all be done automatically.

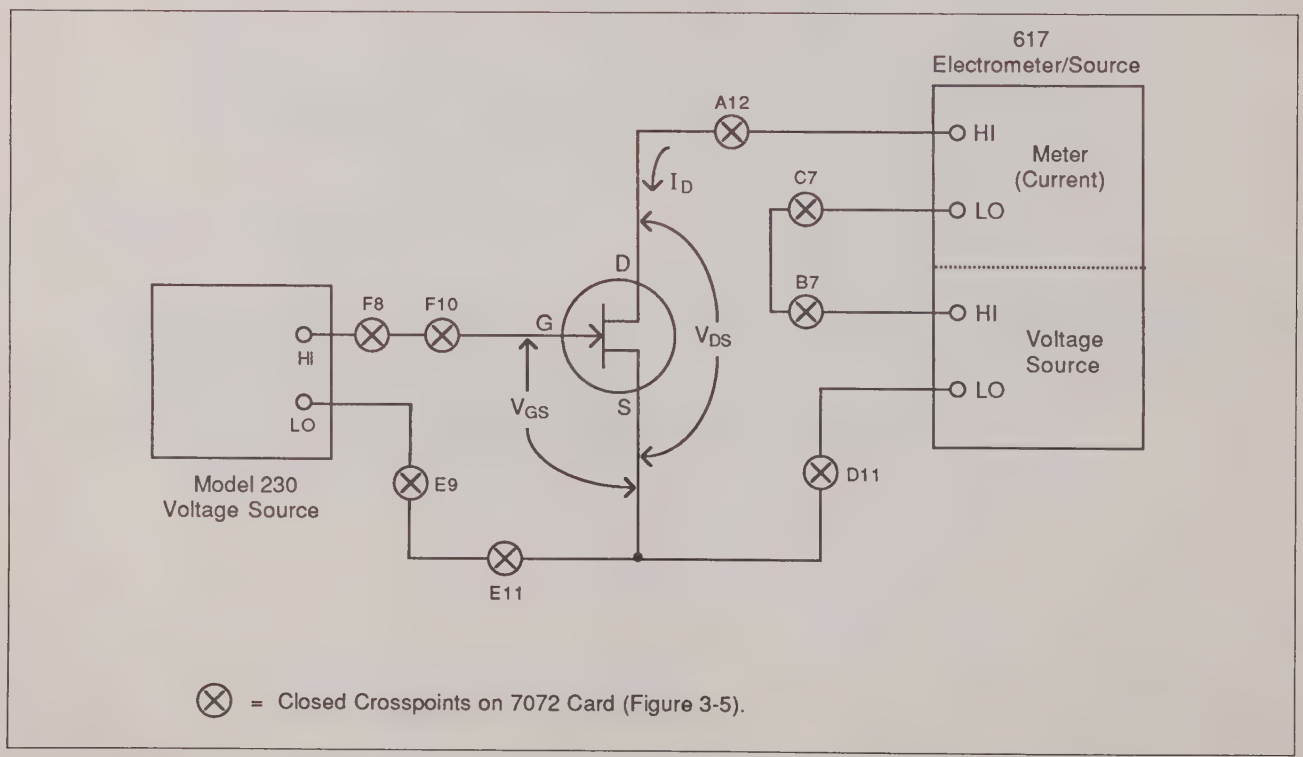


Figure 3-6. System Configuration for Measuring Common-Emitter Characteristics

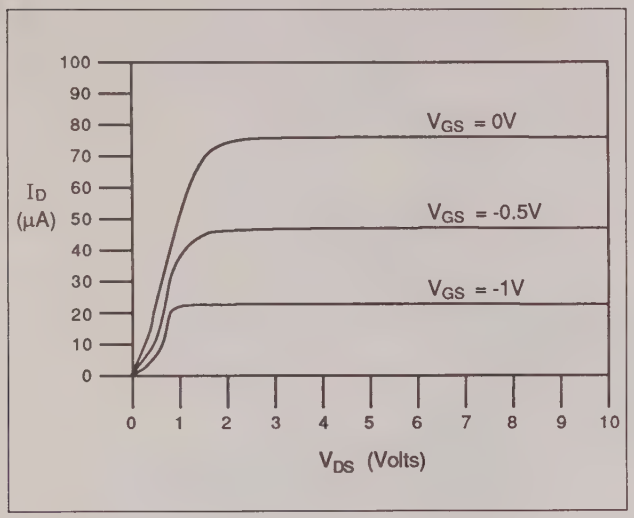


Figure 3-7. Typical Common-Source FET IV Characteristics

3.4 RESISTIVITY MEASUREMENTS

The Model 7072 Semiconductor Matrix card can be used in conjunction with a Model 220 Current Source and a Model 196 DMM to perform resistivity measurements on semiconductors. Such measurements can yield such important information as doping concentration.

3.4.1 Test Configuration

Figure 3-8 shows the basic test configuration to make resistivity measurements on van der Pauw samples. The Model 220 sources current through the samples, while the Model 196 measures the voltage developed across the samples. The matrix card, of course, switches the signal paths as necessary. In order to minimize sample loading, which will reduce accuracy, the Model 196 DMM should be used only on the 300mV or 3V ranges. Also, this configuration is not recommended for resistance measurements above 1MΩ due to the accuracy-degrading effects of DMM loading.

3.4.2 Test Procedure

In order to make van der Pauw resistivity measurements, four terminals of a sample of arbitrary shape are measured. A current (from the Model 220) is applied to two terminals, while the voltage is measured (by the Model 196) across the two opposite terminals, as shown in Figure 3-9. A total of eight such measurements on each sample are required, with each possible terminal and current convention. The resulting voltages are designated V_1 through V_8 .

In order to source current into and measure the voltage across the sample, specific crosspoints must be closed. Table 3-2 summarizes the crosspoints to close for each voltage measurement on all three samples from the test configuration shown in Figure 3-8.

3.4.3 Resistivity Calculations

Once the eight voltage measurements are known, the resistivity can be calculated. Two values of resistivity, p_A and p_B are initially computed as follows:

$$p_A = \frac{1.1331\ f_A\ t_S\ (V_2 + V_4 - V_1 - V_3)}{I}$$

$$p_B = \frac{1.1331\ f_B\ t_S\ (V_6 + V_8 - V_5 - V_7)}{I}$$

Where: p_A and p_B are the resitivities in Ω-cm
t_S is the sample thickness in cm
V_1 through V_8 are the voltages measured by the Model 196
I is the current through the sample in amperes
f_A and f_B are geometrical factors based on sample symmetry ($f_A = f_B = 1$ for perfect symmetry).

Once p_A and p_B are known, the average resistivity, p_{AVG}, can be determined as follows:

$$p_{AVG} = \frac{p_A + p_B}{2}$$

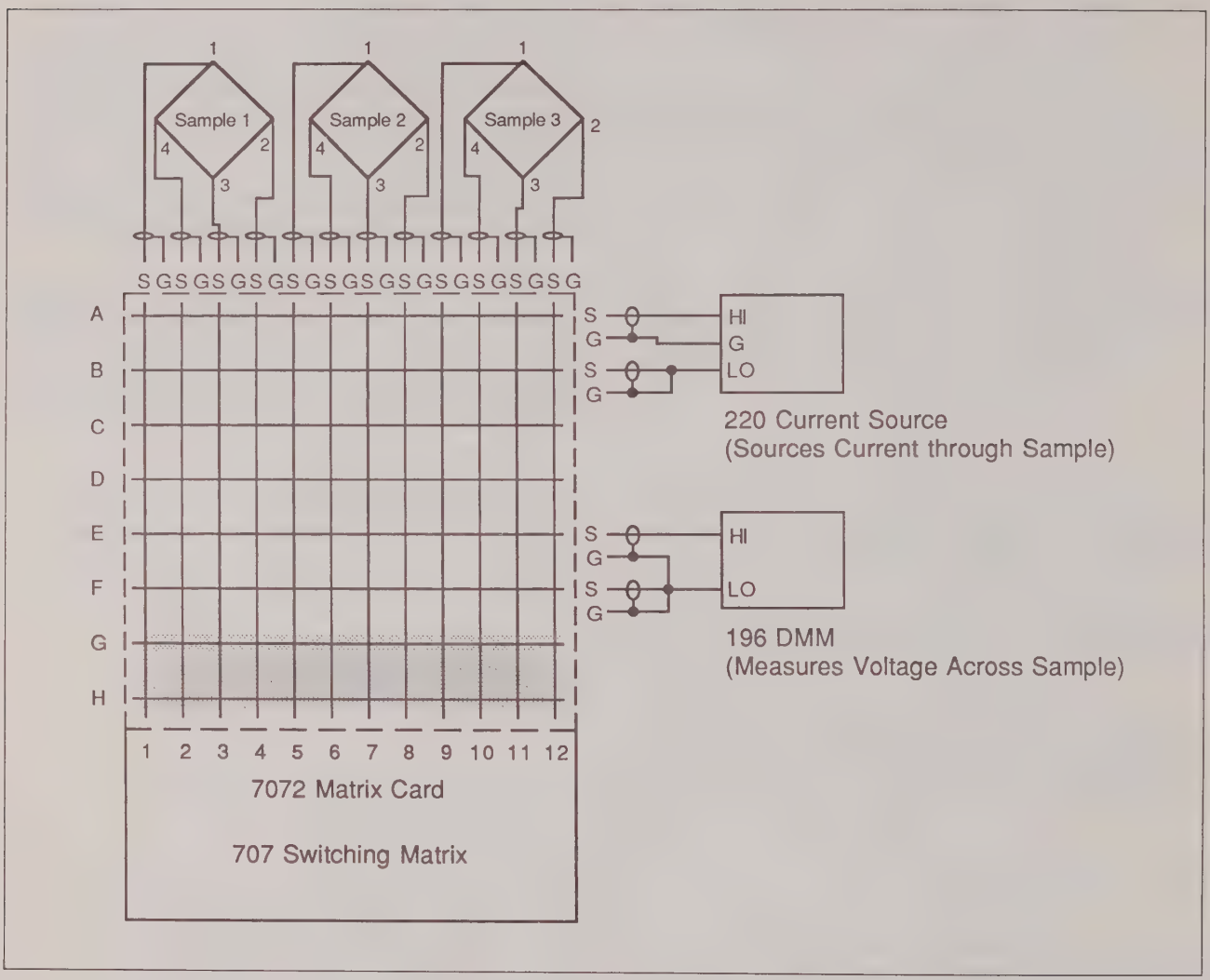


Figure 3-8. Resistivity Test Configuration

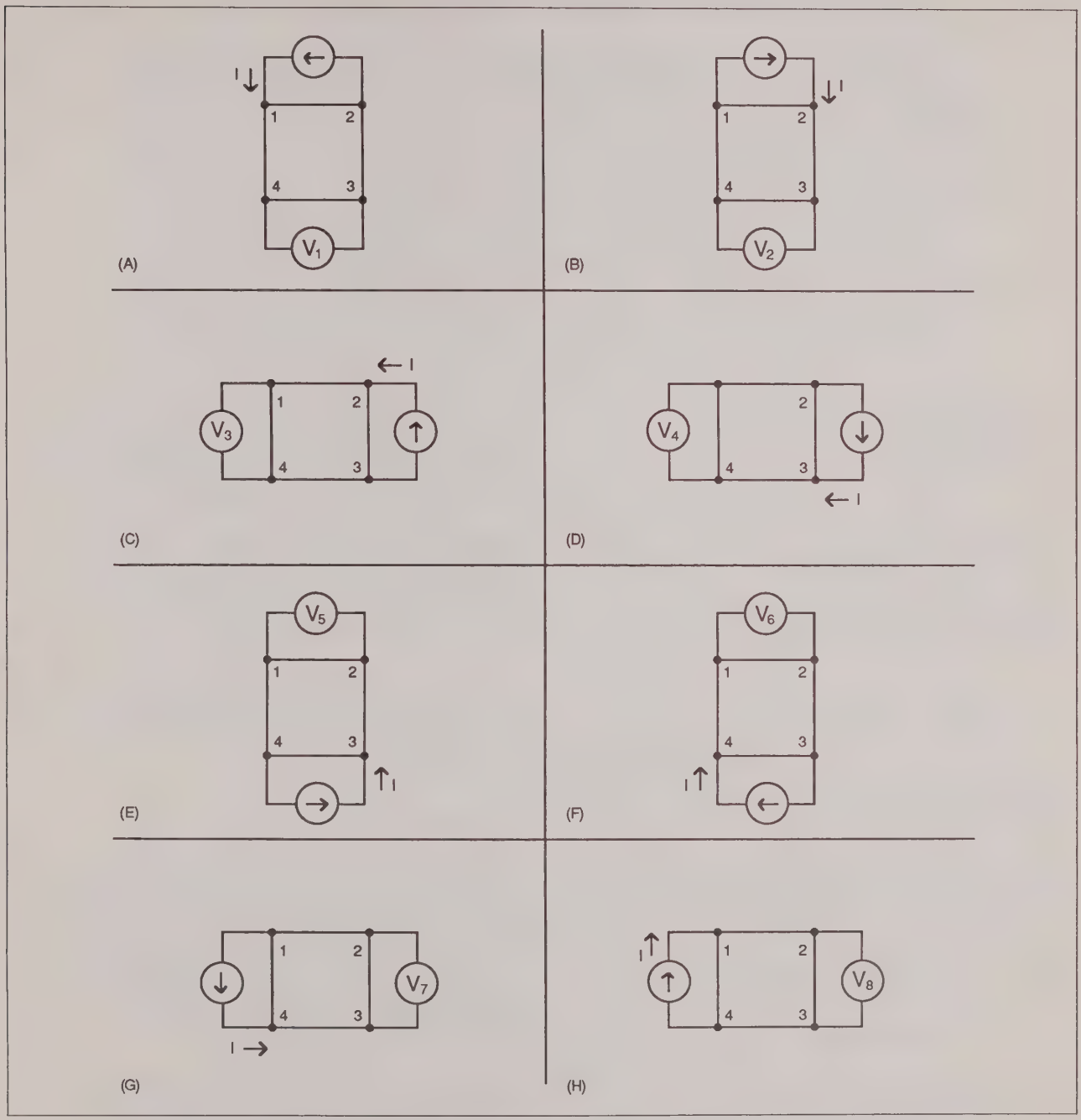


Figure 3-9. Resistivity Measurement Conventions

Table 3-2. Crosspoint Summary for Resistivity Measurements

Voltage	Crosspoints Closed												Current Between	Voltage Between
	Sample #1				Sample #2				Sample #3					
V_1	A1	B4	E3	F2	A5	B9	E7	F6	A9	B12	E11	F10	1-2	3-4
V_2	A4	B1	E3	F2	A8	B5	E7	F6	A12	B9	E11	F10	2-1	3-4
V_3	A4	B3	E2	F1	A8	B7	E6	F5	A12	B11	E10	F9	2-3	4-1
V_4	A3	B4	E2	F1	A7	B8	E6	F5	A11	B12	E10	F9	3-2	4-1
V_5	A3	B2	E1	F4	A7	B6	E5	F8	A11	B10	E9	F12	3-4	1-2
V_6	A2	B3	E1	F4	A6	B7	E5	F8	A10	B11	E9	F12	4-3	1-2
V_7	A2	B1	E4	F3	A6	B5	E8	F7	A10	B9	E12	F11	4-1	2-3
V_8	A1	B2	E4	F3	A5	B6	E8	F7	A9	B10	E12	F11	1-4	2-3

3.5 SEMICONDUCTOR PARAMETER ANALYSIS

One or more Model 7072 Semiconductor Matrix Cards can be used in conjunction with an HP 4145B Semiconductor Parameter Analyzer (SPA) to provide a versatile switching system capable of complete DC characterization of semiconductors. The following paragraphs discuss system configuration, connections using the 7078-CSHP Cable Set, and SPA measurement considerations.

3.5.1 System Configuration

Figure 3-10 shows the general configuration of the SPA switching system. The components of the system perform the following functions:

HP 4145B: Has four SMUs (Source/Measure Units), two voltage sources, and two voltage measurement ports. The unit can automatically run a variety of tests on semiconductors and plot data on a built-in CRT.

Model 707 Switching Matrix: Controls the matrix card to open and close signal paths as required.

Model 7072 Semiconductor Matrix Card: Switches the test pathways to the device under test. In this particular application, three Model 7072 cards provide 36-pin test capability. A total of six cards can be installed in a single mainframe, providing up to 72-pin capability in one mainframe.

System Controller: Controls the SPA and switching matrix with user-written software. Typical controllers for this application are HP 9000 Series 200 or 300 (with HP-IB interface), and IBM PC, AT or compatible computers (equipped with an IEEE-488 interface).

Test Fixture: Provides the interface between the device under test and the matrix card. Typically, the test fixture will be equipped with triax connectors for ease of connections.

3.5.2 Cable Connections

Figure 3-11 shows how to connect the HP 4145B to the Model 7072 using the optional Keithley Model 7078-CSHP Cable Set. The four SMU ports are to be connected with the triax cables (7078-TRX-10), while the two voltage source and voltage measurement ports (Vs and Vm) are to be connected using BNC cables (7051-10) and triax-BNC adapters (7078-TRX-BNC). Typically, the SPA will be connected to the rows, as shown in Figure 3-11.

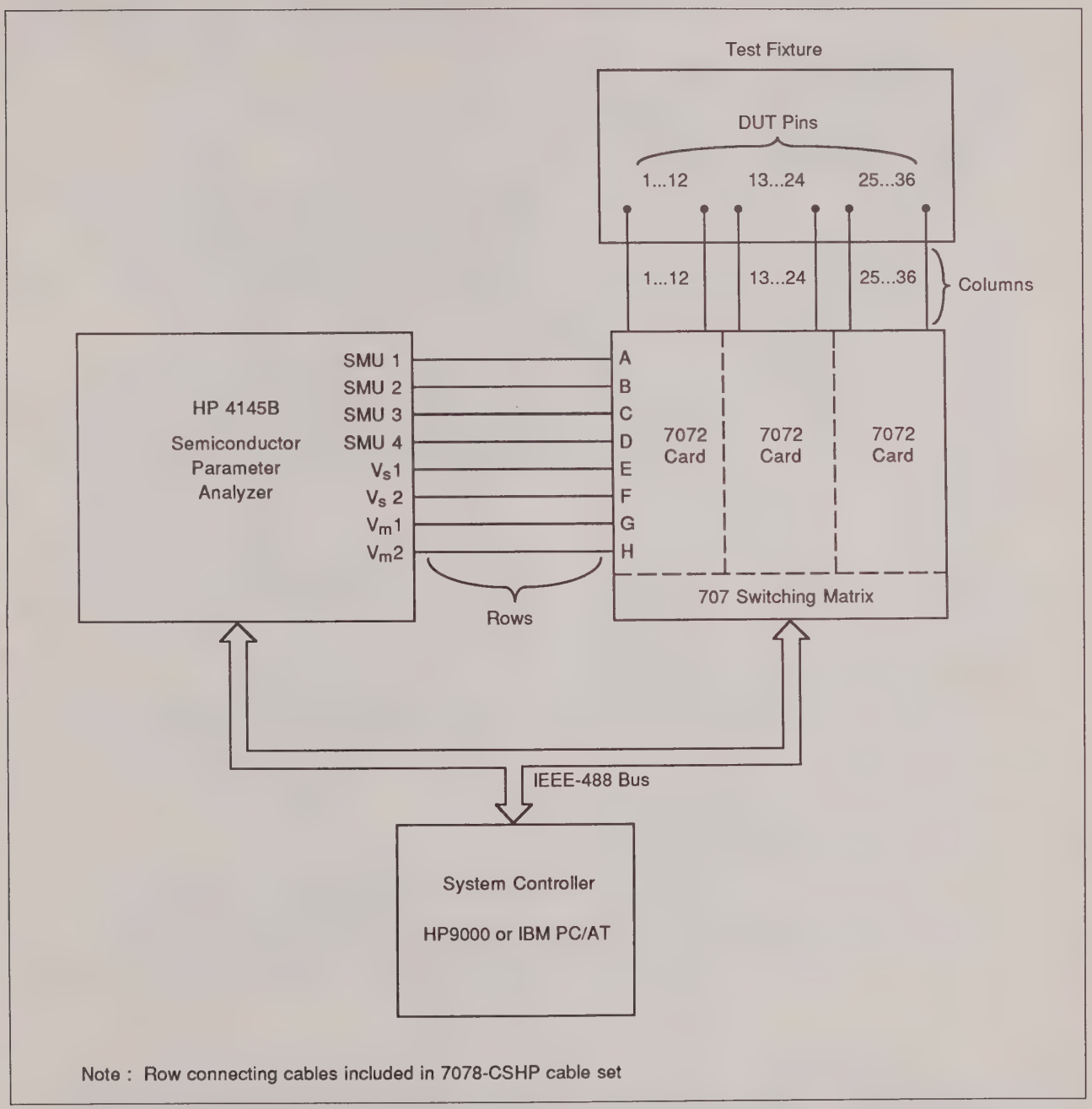


Figure 3-10. Semiconductor Parameter Analysis Switching System

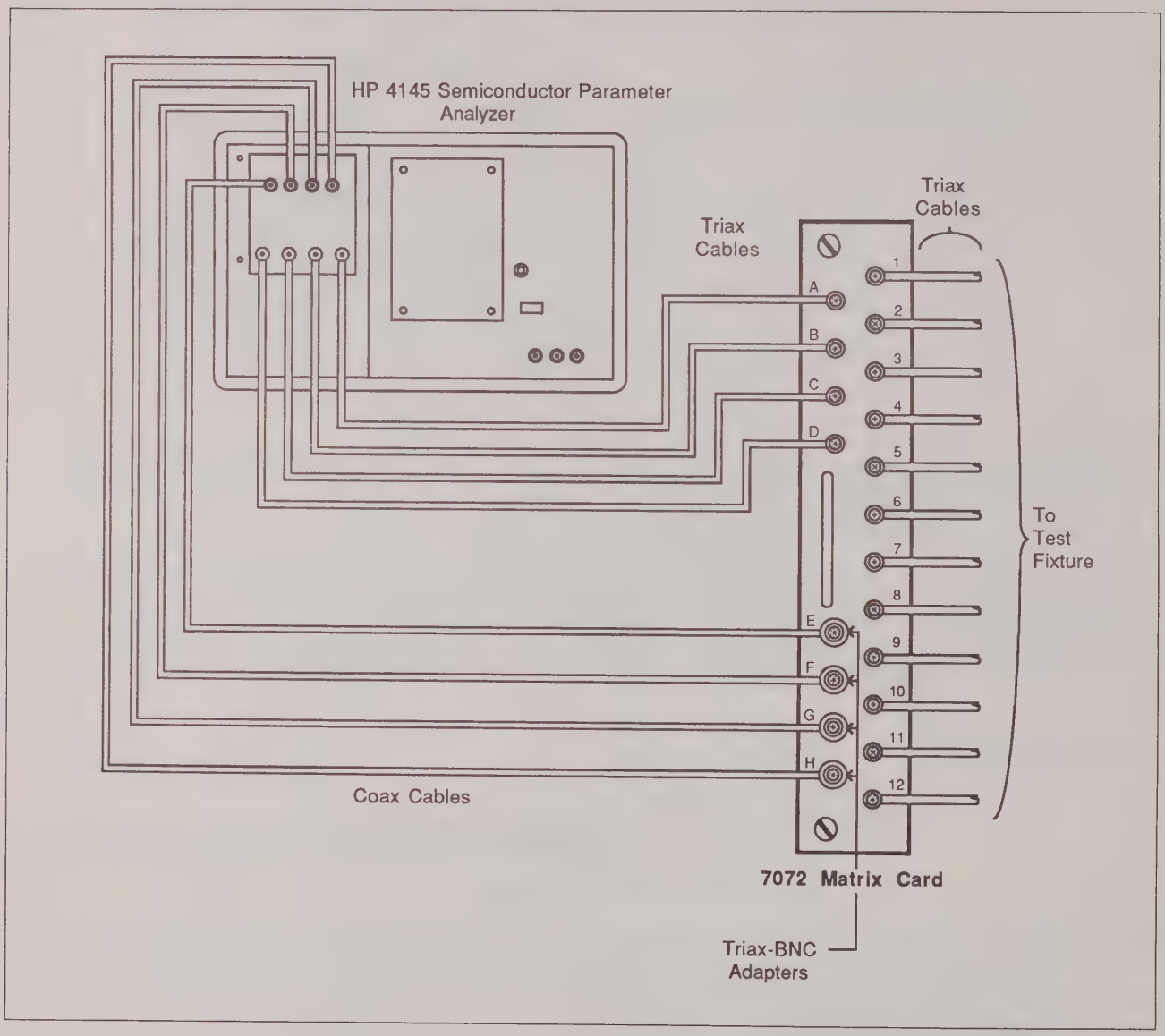


Figure 3-11. SPA Connections

Connections to a user-supplied test fixture should be made using triax cables in order to maintain path integrity and safety. BNC cables and adapters should not be used in case hazardous potential appears on guard terminals.

3.5.3 SPA Measurement Considerations

A complete discussion of SPA measurements is well beyond the scope of this manual. However, there are a few points that should be kept in mind when using this arrangement. Additional measurement considerations may be found in Section 2, paragraph 2.7 of this instruction manual.

Any switching system can degrade low-level signals, and the same hold true for the system shown in Figure 3-10. Since rows A and B on the Model 7072 are dedicated low current pathways, the SMUs that will source or sense low-level signals should be connected only to these rows. The remaining rows can be used for less-critical signals.

Safety considerations are also a concern when connecting instruments to a switching matrix. Therefore, it is strongly recommended that you carefully read the HP 4145B manual before using the system.

WARNING

Hazardous voltage may be present on the outer conductors of the connecting cables when the HP 4145B is set up for floating measurements.

3.5.4 Typical Test Procedure

The following paragraphs outline the procedure for using the SPA/matrix system to perform a typical test: V_{DS}—I_D (common-source) curves of a typical JFET. The procedure uses one of the four standard setups that are part of the applications package supplied with the HP 4145B.

System Configuration

Figure 3-12 shows the configuration and connections for this example. Only three of the four SMUs are required for the test, as indicated in the figure. A total of four FETs can be connected to a single card, as shown on the diagram. In all cases, triax cabling should be used. The crosspoints to close to test a specific FET are summarized in Table 3-3.

Table 3-3. Crosspoint Summary for JFET Test

JFET Tested	Crosspoints Closed* (Source, Gate, Drain)
1	A2, C1, B3
2	A5, C4, B6
3	A8, C7, B9
4	A11, C10, B12

* Crosspoints from Figure 3-12.

Procedure

1. Connect the system and devices together, as shown in Figure 3-12.
2. Turn on the HP 4145B and allow it to go through its boot-up routine.
3. Turn on the Model 707 Switching Matrix.
4. From the HP 4145B main menu, select the channel definition page, then choose the FET V_{DS}—I_D application.
5. Press the PAGE NEXT key, and program the source parameters, as required.
6. Press the PAGE NEXT key, and program the required graphing parameters.
7. Press the PAGE NEXT key to display the graph format.
8. From the front panel of the Model 707, close the crosspoints necessary to connect the FET being tested to the SMUs (see Table 3-3).
9. Press the MEASUREMENT SINGLE key to initiate the sweep. The SPA will generate the I_D vs. V_{DS} curves at specified V_{GS} values.
10. Open the crosspoints presently closed.
11. Repeat steps 8 and 9 for the remaining devices, as required.

Typical Plot

Figure 3-13 shows a typical plot made using the procedure above. The device tested was a 2N4392 N-channel JFET. For the graphs, V_{DS} was swept from 0V to 10V in 0.1V increments, and V_{GS} was stepped from 0 to −0.25V.

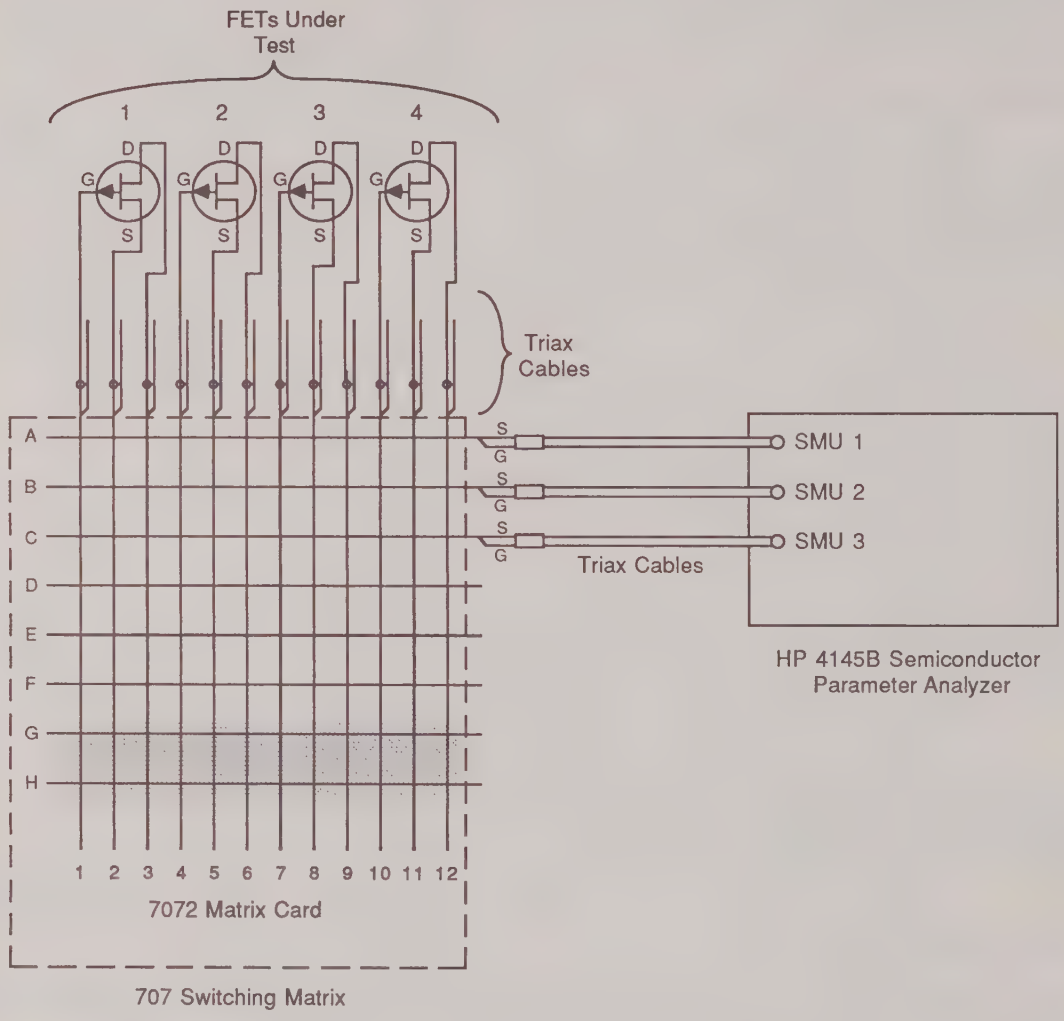


Figure 3-12. System Configuration for JFET Test

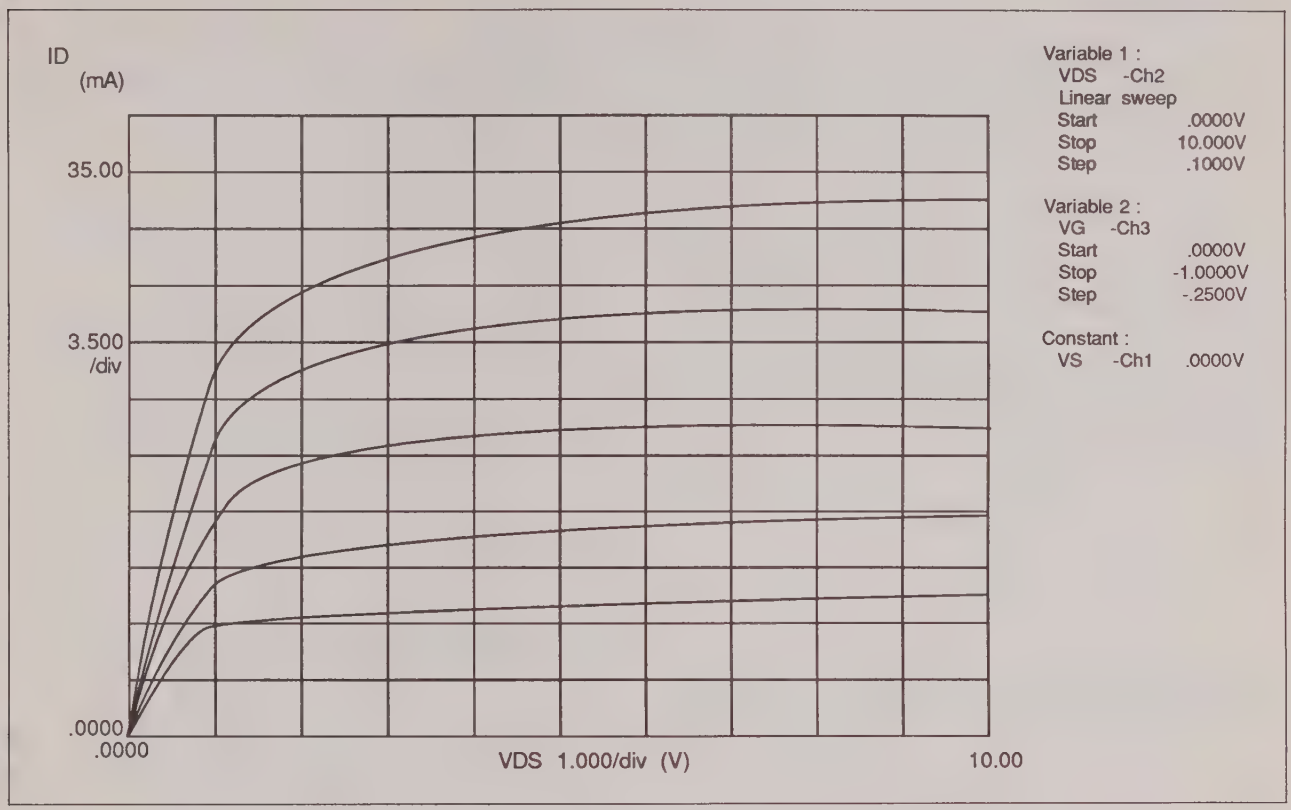


Figure 3-13. Typical JFET Plot

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SECTION 4
Service Information

4.1 INTRODUCTION

This section contains information necessary to service the Model 7072 Semiconductor Matrix Card and is arranged as follows:

4.2 **Handling and Cleaning Precautions:** Discusses handling precautions and methods to clean the card should it become contaminated.

4.3 **Performance Verification:** Covers the procedures necessary to determine if the card is operating properly.

4.4 **Special Handling of Static-Sensitive Devices:** Reviews precautions necessary when handling static-sensitive devices.

4.5 **Troubleshooting:** Presents some troubleshooting tips for the Model 7072.

4.6 **Principles of Operation:** Briefly discusses circuit operation.

4.2 HANDLING AND CLEANING PRECAUTIONS

Because of the high-impedance circuits on the Model 7072, care should be taken when handling or servicing the card to prevent possible contamination. The following precautions should be taken when servicing the card.

1. Handle the card only by the edges and handle (do not touch the edge connectors). Do not touch any board surfaces or components not associated with the repair.
2. Do not store or operate the card in an environment where dust could settle on the circuit board. Use dry nitrogen gas to clean dust off the board if necessary.
3. Should it become necessary to use solder on the circuit board, remove the flux from the work areas when the repair has been completed. Use Freon® TMS or TE or the equivalent along with clean cotton swabs or a clean, soft brush to remove the flux. Take care not to spread the flux to other areas of the circuit board. Once the flux has been removed, swab only the repaired area with methanol, then blow dry the board with dry nitrogen gas.
4. After cleaning, the card should be placed in a 50°C low-humidity environment for several hours before use.

4.3 PERFORMANCE VERIFICATION

The following paragraphs discuss performance verification procedures for the Model 7072, including relay testing, contact resistance, contact potential, path isolation, and leakage current.

4.3.1 Environmental Conditions

All verification measurements except for path isolation and offset current should be made at an ambient temperature between 0°C and 35°C and at a relative humidity of less than 70%. Path isolation and offset current verification must be performed at an ambient temperature of 23°C and at a relative humidity of less than 60% If the matrix card has be subjected to temperature or humidity extremes, allow the card to environmentally stabilize for at least one hour before performing any tests.

4.3.2 Recommended Test Equipment

Table 4-1 summarizes the equipment necessary to make the performance verification tests, along with the application for each item.

Table 4-1. Recommended Verification Equipment

Qty	Description	Application
1	Model 617 Electrometer	Offset current; path isolation
1	Model 196 6½ Digit DMM	Path resistance
1	Model 707 Switching Matrix	All tests
1	IBM PC or HP 200 or 300 computer	Relay test
4	Model 7078-TRX-10 triax cables*	Offset current; path resistance
2	Model 7078-TRX-3 triax cables	Path isolation, offset current
1	Model 6172 2-slot male to 3-lug female triaxial adapter	Offset current
3	Model 7078-TRX-T triax tee adapter	Path resistance
5	Banana plugs (part #B6-10-2)*	Path isolation and resistance
1	Relay test terminal block*	Relay test

*These items are used to construct special cables; see text.

4.3.3 Relay Testing

The relays on Model 7072 can be tested using the test software supplied with the Model 707 Switching Matrix. The following paragraphs discuss the test equipment and connections. For detailed information on using the test software, consult Section 6 of the Model 707 Instruction Manual.

Recommended Equipment

- Model 707 Switching Matrix
- Unterminated 3-slot triax cables (2), made by cutting one TRX-7078-10 cable in half
- Relay test software (supplied with Model 707)
- IBM PC compatible or Hewlett Packard Series 200 or 300 computer
- Relay test connector (supplied with Model 707)

Connections

The test cable should be prepared using the information shown in Figure 4-1. The center conductor of the unterminated end of one triax cable should be connected to pin 1 of the relay test connector, while the inner shield should be connected to pin 2. The outer shield should be cut off and be left floating at the test connector end.

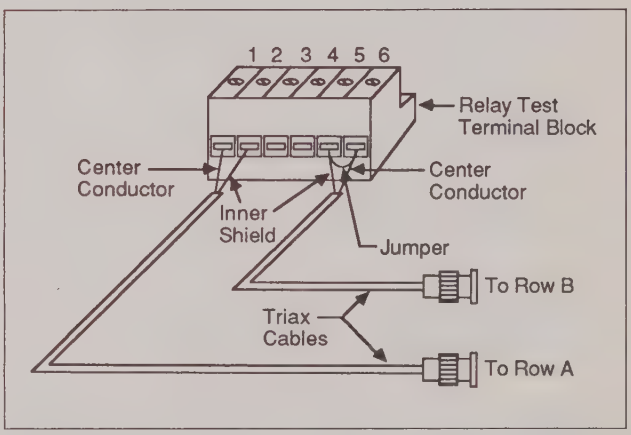


Figure 4-1. Test Cable Preparation

The remaining triax cable should be connected as follows: connect the center conductor to pin 6, and connect the inner shield to pin 5. Again, the outer shield should be left floating. Also, jumper pins 5 and 6 of the relay test connector together.

Figure 4-2 shows how to connect the prepared test cable to the Model 7072. Connect the first triax cable to row A of the card, and connect the second triax cable to row B. Also be sure to connect the test connector to the RELAY TEST jack on the rear panel of the Model 707.

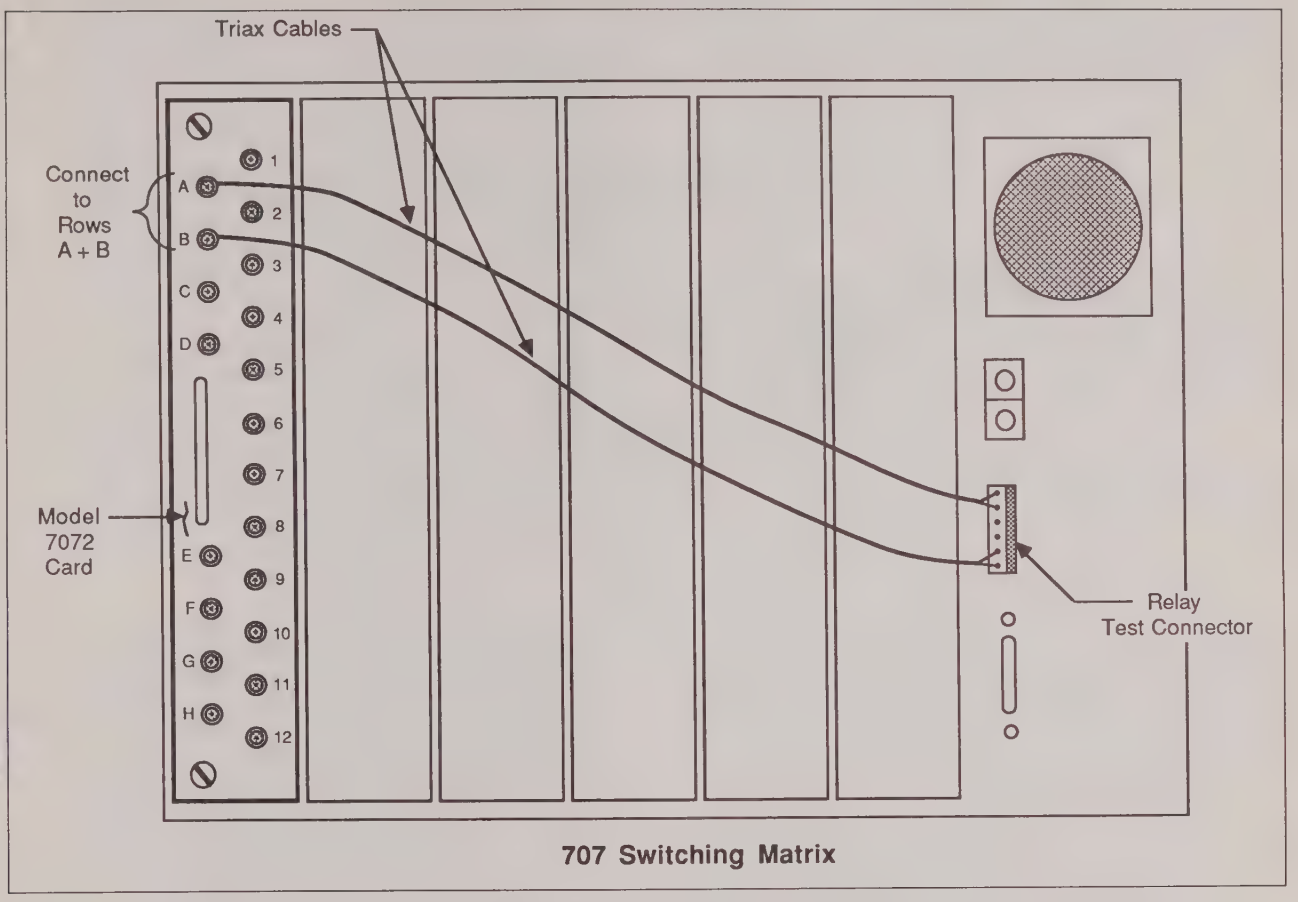


Figure 4-2. Connecting the Test Cable to the Model 7072

Running the Test

Follow the instructions given in the Model 707 Instruction Manual to perform the relay test. The computer will advise you as to which relay or group of relays (if any) fail to pass the test.

4.3.4 Offset Current Verification

Recommended Equipment

- Model 707 Switching Matrix
- Model 617 Electrometer
- Model 7078-TRX-3 Triax Cable
- Model 6172 2-slot male to 3-lug female triaxial adapter

Test Connections

Figure 4-3 shows the test connections for offset current verification. The Model 7072 row being tested is to be connected to the Model 617 Electrometer input through the triaxial cable and the triaxial adapter. Note that the electrometer ground strap is to be removed, and the electrometer should be operated in the unguarded mode.

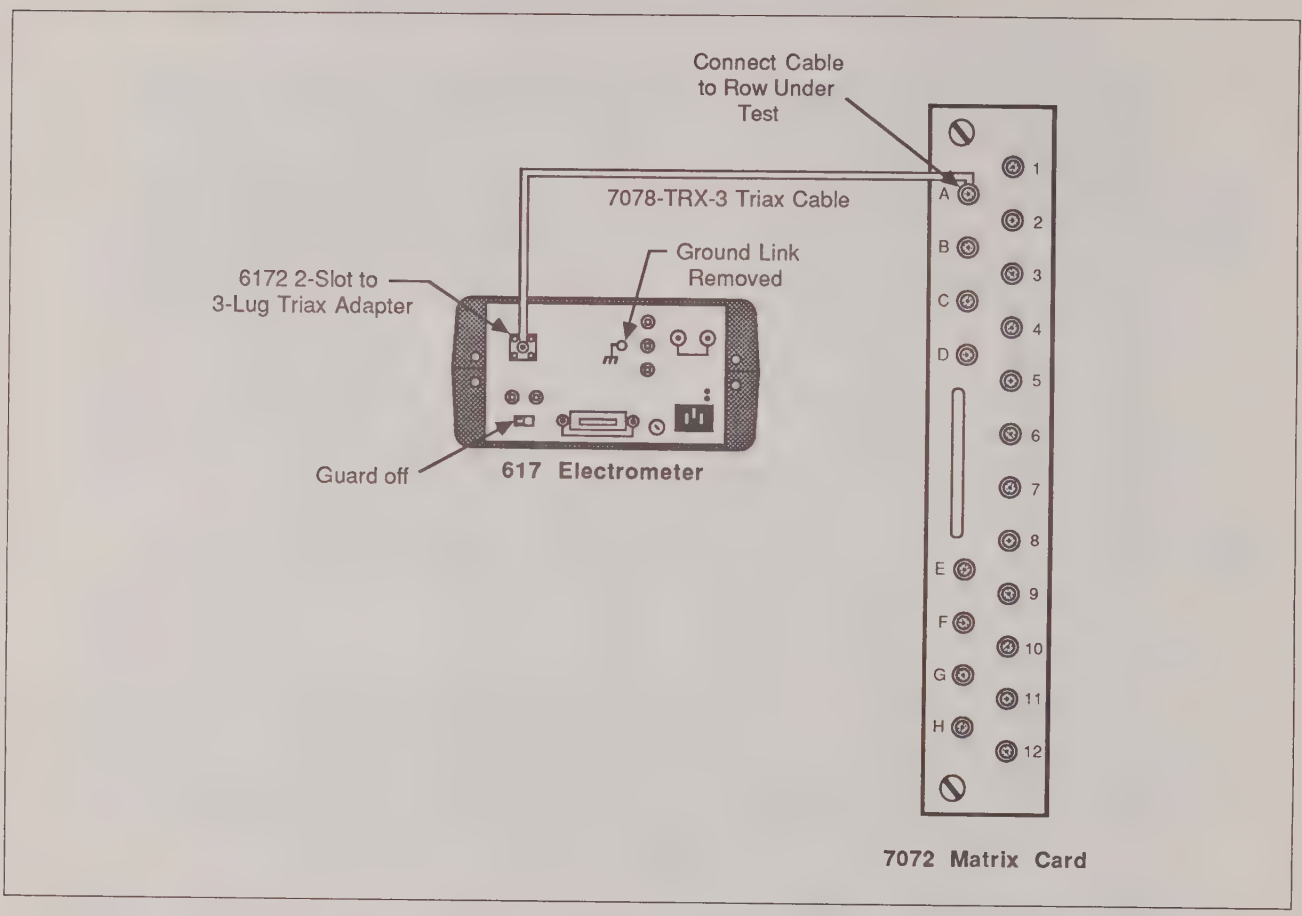


Figure 4-3. Offset Verification Test Connections

Procedure

NOTE

The following procedure should be performed at an ambient temperature of 23°C and at a relative humidity of less than 60%.

1. Turn on the Model 617 power and allow it to warm up for two hours before beginning the verification procedure.
2. With the power off, install the Model 7072 in the desired slot of the Model 707 Switching Matrix. Remove all other cards from the instrument, and install the slot covers.
3. After the prescribed warm up period, select the amps function and the 2pA range on the Model 617. Zero correct the instrument, and then select autoranging.
4. Connect the Model 617 to row A of the Model 7072, as shown in Figure 4-3.
5. Close crosspoint A1 by using the Model 707 front panel controls.
6. Disable zero check on the Model 617, and allow the reading to settle.
7. Verify that the offset current reading is <1pA.
8. Enable zero check on the Model 617, and open crosspoint A1.
9. Repeat steps 5 through 8 for crosspoints A2 through A12. Only one crosspoint at a time should be closed.
10. Disconnect the triax cable from row A, and connect it instead to row B.
11. Repeat steps 5 through 8 for crosspoints B1 through B12. Only one crosspoint at a time should be closed.
12. With zero check enabled, disconnect the electrometer from row B, and connect it to row C.

13. Close crosspoint C1 by using the front panel controls of the Model 707.
14. Disable zero check, and allow the reading to settle.
15. Verify that the offset current reading is <20pA.
16. Enable zero check, then open the crosspoint presently closed.
17. Repeat steps 12 through 16 for rows D through H. The electrometer should be connected to the row being tested, and only one crosspoint must be closed at a time. The offset current for each crosspoint should be <20pA.

4.3.5 Path Isolation Verification

The procedure for verifying path isolation is discussed below. Should the card fail any of the tests, clean it using the procedures outlined in paragraph 4.2. If rows C through F still fail, the problem may lie in contamination of the mainframe backplane.

NOTE

If the path isolation for specific rows is below standards, test the associated rows or columns with the card removed from the mainframe. (Of course, it will not be possible to close crosspoints with the card removed.) If rows C-F pass with the card removed but fail with the card installed, the backplane in the mainframe may require cleaning. See the Model 707 Instruction Manual.

Recommended Equipment

- Model 707 Switching Matrix
- Model 617 Electrometer
- Model 7078-TRX-3 triaxial cable
- Unterminated 3-slot triaxial cable (cut connector off 7078-TRX-3)
- Banana plug (Keithley part #BG-10-2)
- #16-18AWG insulated stranded wire (6 in. length)

Test Connections

Figure 4-4 shows the test connections for the path isolation tests. One row being tested is to be connected to the Model 617 Electrometer input through a Model 6172 2-slot female to 3-lug male triaxial adapter. The other row is to be connected to the voltage source HI terminal using a specially prepared 3-slot triax-to-banana plug cable, the construction of which is shown in Figure 4-5. Note that both the inner shield and the center conductor are to be connected to the banana plug as shown.

COM and the LO terminal of the electrometer voltage source must be connected together as shown. Also, the ground link between COM and chassis must be removed, and the Model 617 guard must be turned off for current measurements.

Procedure

WARNING

Hazardous voltage from the electrometer voltage source will be used in the following steps. Take care not to contact live circuits, which could cause personal injury or death.

NOTE

The following procedure must be performed at an ambient temperature of 23°C and at a relative humidity of less than 60%.

1. Turn on the Model 617 and allow it to warm up for two hours for rated accuracy.
2. With the mainframe power turned off, plug the Model 7072 into slot 1 of the mainframe. Remove all other cards from the mainframe, and install the slot covers.
3. After the prescribed warm up period, select the Model 617 amps function, and enable zero check. Select the 2pA range, and zero correct the instrument.
4. Connect the Model 617 to rows A and B of the matrix card, as shown in Figure 4-4.
5. Program the Model 617 voltage source for a value of +100V, but do not yet turn on the voltage source output.
6. Close crosspoints A1 and B2 by using the switching matrix front panel controls.
7. With the Model 617 in amps, enable suppress after the reading has settled.
8. Turn on the Model 617 voltage source output, and enable the V/I ohms function on the electrometer.
9. After the reading has settled, verify that the resistance is >10TΩ ($10^{13}\Omega$).
10. Turn off the voltage source, and enable zero check. Disable suppress, and select the amps function on the electrometer.
11. Open crosspoints A1 and B2, and close crosspoints A3 and B4.
12. Repeat steps 7 through 11 for A3 and B4.
13. Repeat steps 7 through 12 for crosspoint pairs A5 and B6, A7 and B8, A9 and B10, and A11 and B12.
14. Disconnect the electrometer from rows A and B, and connect it instead to rows C and D.

15. Repeat steps 7 through 13 for rows C and D. The path isolation for these rows should be >1TΩ ($10^{12}\Omega$).
16. Repeat steps 7 through 14 for row pairs E and F, and G and H. For each row pair, step through the crosspoint pairs 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, and 11 and 12. The complete procedure outlined in steps 7 through 11 should be repeated for each crosspoint pair. Each resistance measurement for rows E through H should be >1TΩ ($10^{12}\Omega$).

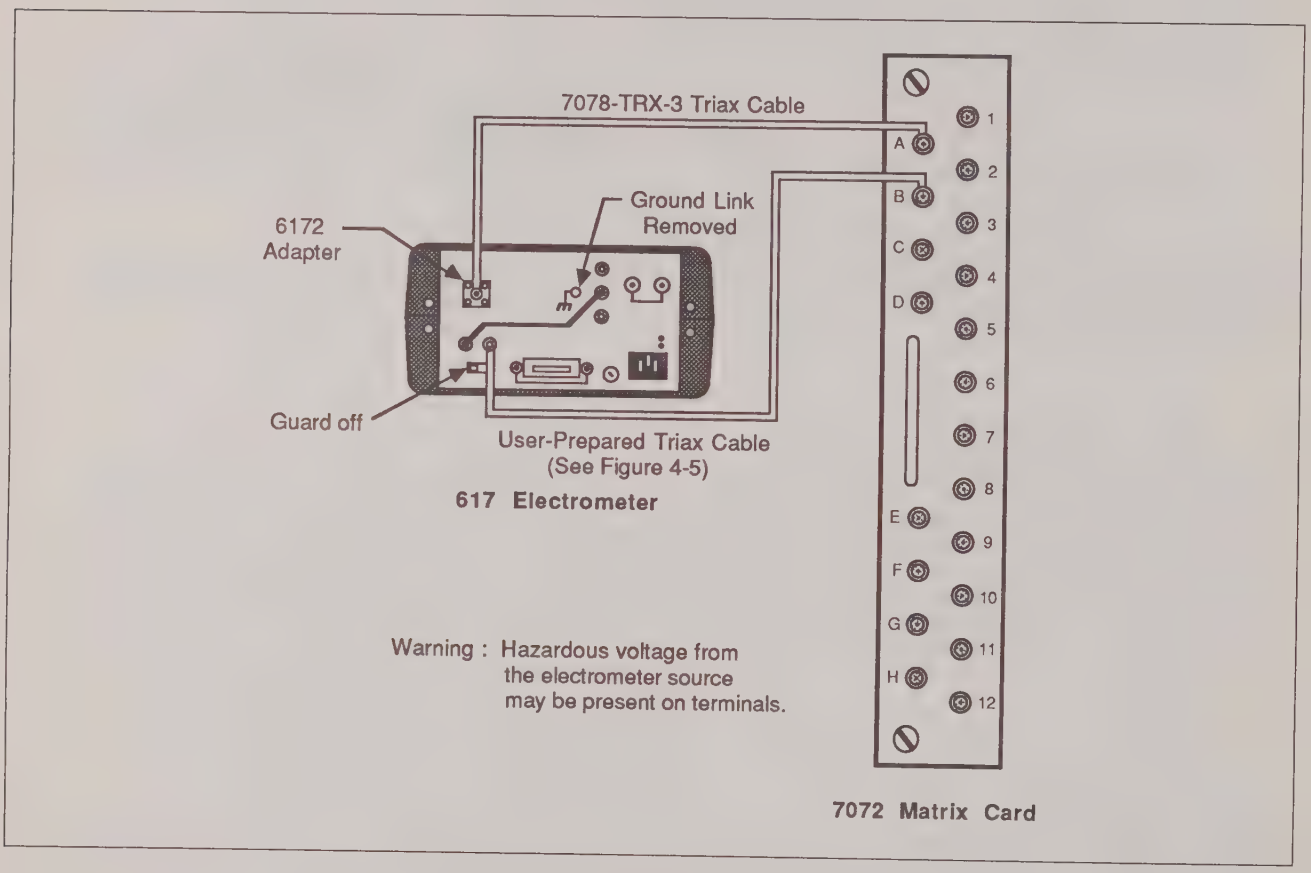
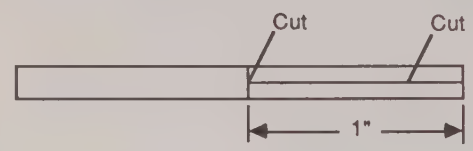
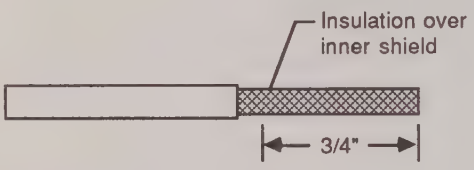


Figure 4-4. Connections for Path Isolation Verification



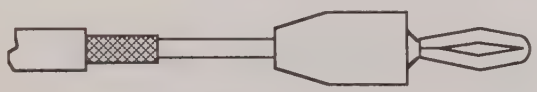
(A) Cut off insulation with knife.
Cut off outer shield.



(B) Strip insulation off inner shield.

(C) Twist inner shield then strip inner conductor.
Twist inner shield and center conductor together,
slip on plastic cover.

(D) Insert wire into hole and rap around body.



(E) Screw on plastic cover.

Figure 4-5. Triaxial Cable Preparation

4.3.6 Path Resistance Verification

The following paragraphs discuss the equipment, connections, and procedure to check path resistance. Should a particular pathway fail the resistance test, the relay (or relays) for that particular crosspoint is probably defective. See the schematic diagram at the end of Section 5 to determine which relay is defective.

Recommended Equipment

- Model 196 DMM
- 7078-TRX-T triax tee adapters (3)
- Unterminated 3-slot triax cables (4), made from two 7078-TRX-10 triax cables.
- Banana plugs (4), Keithley part number BG-10-2

Connections

Figure 4-6 shows the connections for the path resistance tests. The Model 196 is to be connected to the row and column jacks using prepared triax/banana cables (Figure 4-5, but with inner shield and center conductor disconnected.) and 7078-TRX-T triax tee adapters. The special cables can be made from two 7078-TRX-10 cables each cut in half, or four 7078-TRX-3 cables by cutting one triax connector off each cable.

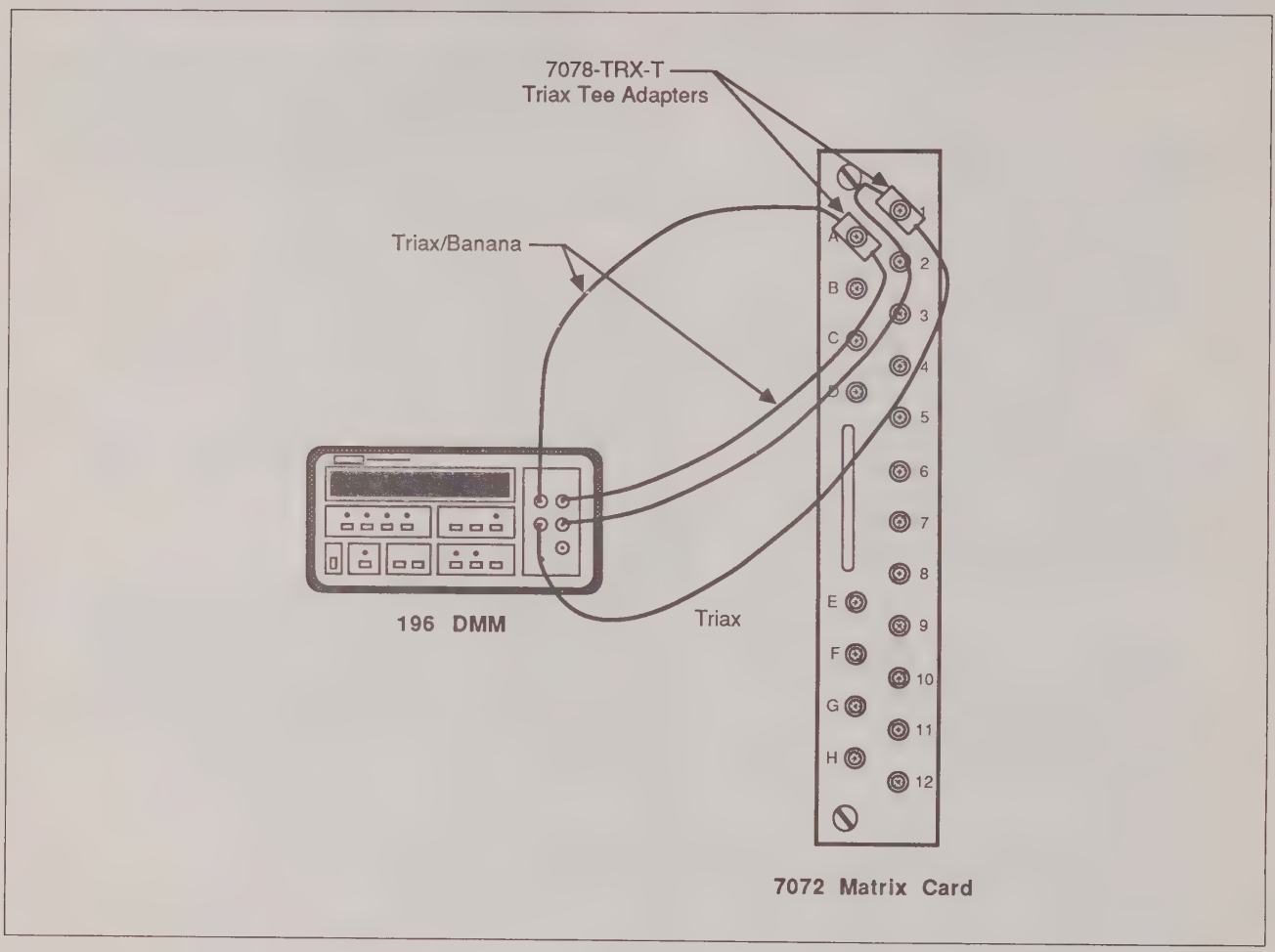


Figure 4-6. Connections for Path Resistance Verification

Procedure

1. Turn on the Model 196 DMM and allow it to warm up for at least one hour before beginning the test.
2. With the power off, install the Model 7072 card in slot 1 of the mainframe.
3. Connect the four triaxial cables to the Model 196 and the two triax tee adapters (Figure 4-6), but do not yet connect the adapters to the Model 7072.
4. Temporarily connect the two triax tee connectors together using a third triax tee adapter, as shown in Figure 4-7.
5. Select the ohms function, 300Ω range, and 6½-digit resolution on the Model 196.
6. After the reading settles, enable zero on the Model 196 DMM. Leave zero enabled for the remainder of the tests.
7. Disconnect the two triax tee adapters from the shorting adapter, and connect the two adapters with the cable to the row A and column 1 connectors on the Model 7072 (see Figure 4-6).
8. Close crosspoint A1, and allow the reading to settle.
9. Verify that the resistance reading is $<3.5\Omega$.
10. Open the crosspoint, and disconnect the triax adapter from column 1. Connect the adapter to column 2.
11. Repeat steps 8 through 10 for columns 2 through 12. In each case, the column adapter must be connected to the column under test, and the crosspoint must be closed.

12. Disconnect the row adapter from row A, and connect it instead to row B.
13. Repeat steps 8 through 10 for row B. The crosspoints of interest here are B1 through B12. Also, the row adapter must be connected to the row being tested.
14. Repeat steps 8 through 13 for rows C through H. In each case, the crosspoint to close is the one corresponding to the row and column connections at that time. In all cases, the measured resistance should be <3.5Ω.

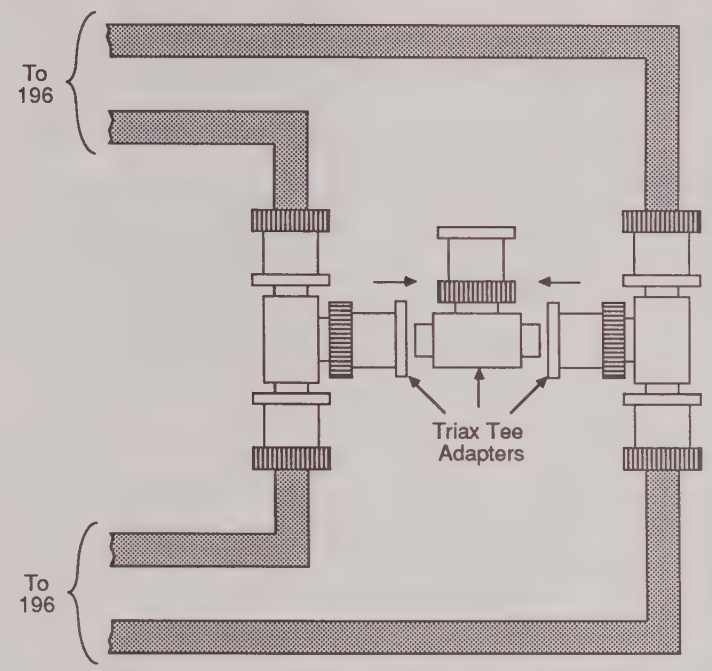


Figure 4-7. Shorting Measurement Paths Using Triax Tee Adapter

4.4 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS and other high-impedance devices are subject to possible static discharge damage because of the high-impedance levels involved. When handling such devices, use the precautions listed below.

NOTE
In order to prevent damage, assume that all parts are static sensitive.

1. Such devices should be transported and handled only in containers specially designed to prevent or dissipate static build-up. Typically, these devices will be received in anti-static containers made of plastic or foam. Keep these parts in their original containers until ready for installation or use.
2. Remove the devices from their protective containers only at a properly-grounded work station. Also ground yourself with an appropriate wrist strap while working with these devices.
3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must first be grounded to the bench or table.
5. Use only anti-static type de-soldering tools and grounded-tip soldering irons.

4.5 TROUBLESHOOTING

4.5.1 Recommended Equipment

Table 4-2 summarizes the recommended equipment for general troubleshooting.

Table 4-2. Recommended Troubleshooting Equipment

Description	Manufacturer and Model	Application
5½-Digit DMM	Keithley 199	Measure DC voltages
Oscilloscope	TEK 2243	View logic waveforms
Extender card	Keithley 7070	Allow circuit access

4.5.2 Using the Extender Card

In order to gain access to the test points and other circuitry on the Model 7072, the card must be plugged into the Model 7070 Extender Card, which, in turn, must be plugged into the desired slot of the mainframe. The Model 7070 must be configured as an extender card by placing the configuration jumper in the EXTEND position. See the documentation supplied with the Model 7070 for complete details on using the card.

NOTE
The Model 7070 cannot be used for performing the verification tests because its presence will affect the results.

4.5.3 Troubleshooting Procedure

Table 4-3 summarizes the troubleshooting procedure for the Model 7072 Semiconductor Matrix Card. Some of the troubleshooting steps refer to the ID data timing diagram shown in Figure 4-8. In addition to the procedure shown, the relay tests outlined in paragraph 4.3.3 can be used to aid in troubleshooting. Also, refer to paragraph 4.6 for an overview of operating principles.

Table 4-3. Troubleshooting Procedure

Step	Item/Component	Required Condition	Comments
1	TP2		All voltages referenced to TP2 (digital common)
2	TP1	+6VDC	Relay voltage
3	TP3	+5VDC	Logic voltage
4	TP4	NEXT ADDR pulses	Power up only (Fig. 4-8)
5	TP5	CLR ADDR pulse	Power up only (Fig. 4-8)
6	TP6	ID data pulses	Power up only (Fig. 4-8)
7	TP7	STROBE pulse	End of relay data sequence.
8	TP8	Relay data (128 bits)	Present when updating relays.
9	TP9	CLK pulses	Present during relay data or ID data.
10	TP10	High on power up until first STROBE sets low.	Power on safe guard.
11	U30-U45, pins 10-18	Low with relay energized, high with relay de-energized.	Relay driver outputs

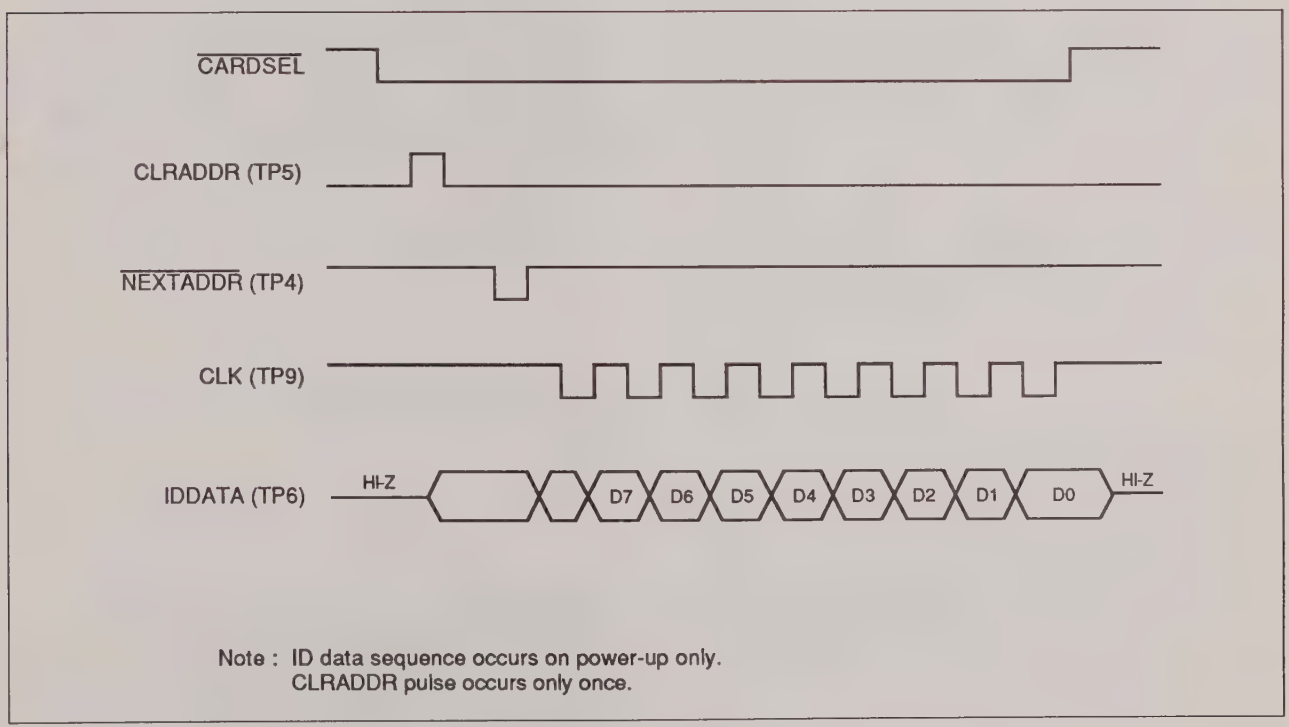


Figure 4-8. ID Data Timing

4.6 PRINCIPLES OF OPERATION

The following paragraphs discuss the basic operating principles for the Model 7072. A schematic diagram of the matrix card may be found in drawing number 7072-106 (four sheets), located at the end of Section 5.

4.6.1 Block Diagram

Figure 4-9 shows a simplified block diagram of the Model 7072. Key elements include the buffer (U46), ID data circuits (U14, U27, and U47), relay drivers (U30-U45) and relays (K1-K128), and power-on safe guard (U29). The major elements are discussed below.

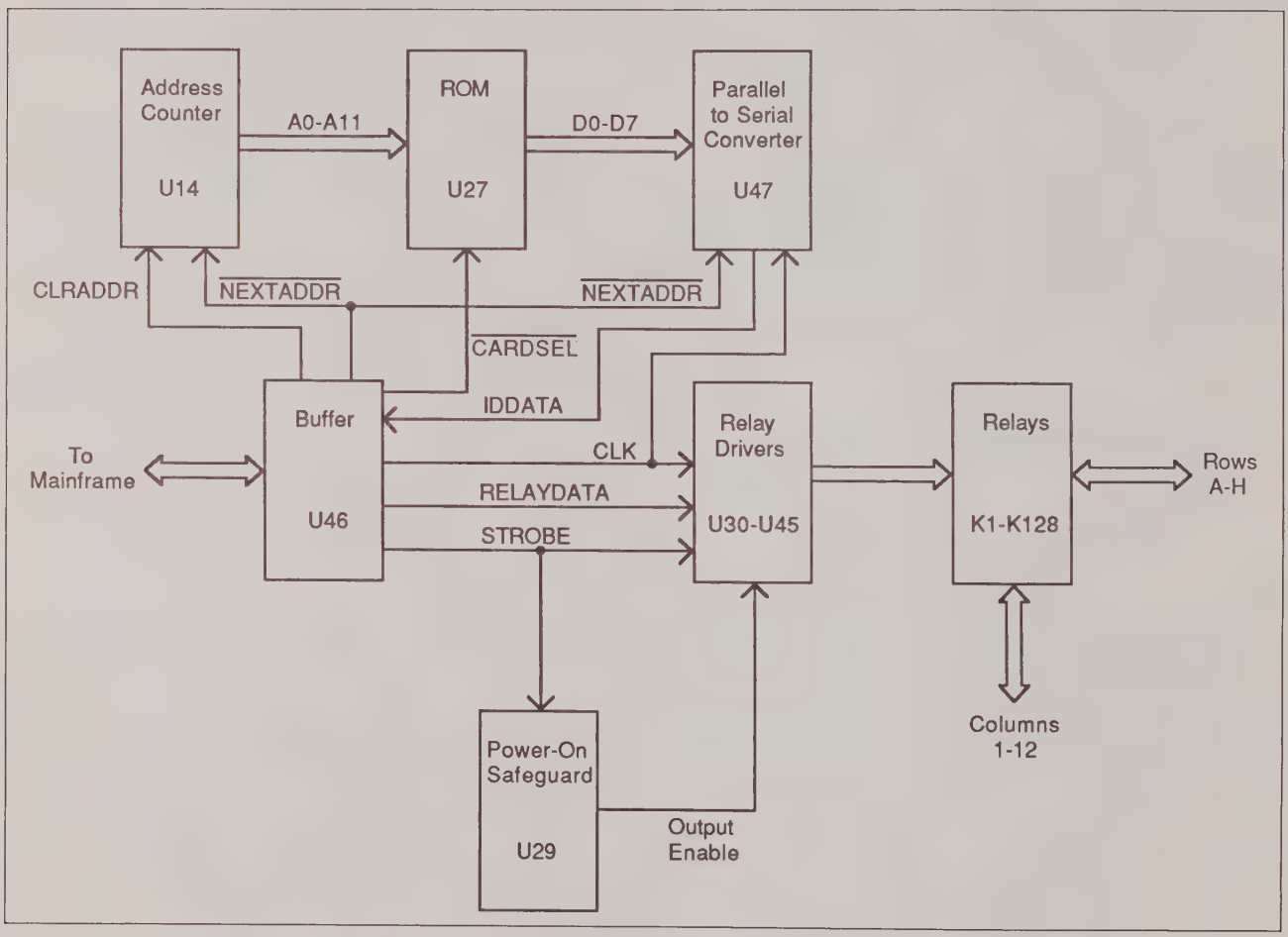


Figure 4-9. Model 7072 Block Diagram

4.6.2 ID Data Circuits

Upon power up, the card identification data information from each card is read by the mainframe. This ID data includes such information as card ID, hardware settling time for the card, and a relay configuration table, which tells the mainframe which relays to close for a specific crosspoint. This configuration table is necessary because some cards (such as the Model 7072) require the closing of more than one relay to close a specific crosspoint.

ID data is contained within an on-card ROM, U27. In order to read this information, the sequence below is performed upon power up. Figure 4-8 shows the general timing of this sequence.

1. The CARDSEL line is brought low, enabling the ROM outputs. This line remains low throughout the ID data transmission sequence.
2. The CLRADDR line is pulsed high to clear the address counter and set it to zero. At this point, a ROM address of zero is selected. This pulse occurs only once.
3. The NEXTADDR line is set low. NEXTADDR going low increments the counter and enables parallel loading of the parallel-to-serial converter. NEXTADDR is kept low long enough for the counter to increment and the ROM outputs to stabilize. This sequence functions because the load input of the parallel-to-serial converter is level sensitive rather than edge sensitive. The first ROM address is location 1, not 0.
4. The CLK line clocks the parallel-to-serial converter to shift all eight data bits from the converter to the mainframe via the IDDATA line.

The process in steps 3 and 4 repeats until all the necessary ROM locations have been read. A total of 498 bytes of information are read by the mainframe during the card ID sequence.

4.6.3 Relay Control

The relays are controlled by serial data transmitted via the RELAYDATA line. A total of 16 bytes for each card are shifted in in serial fashion into latches located in the 16 relay drivers, U30-U45. The serial data is fed in through the DATA lines under control of the CLK signal. As data overflows one register, it is fed out the Q'S line of that register to the next IC down the chain.

Once all 16 bytes have been shifted into each card in the mainframe, the STROBE line is set high to latch the relay information into the Q outputs of the relay drivers, and the appropriate relays are energized (assuming the driver outputs are enabled, as discussed below). Logic convention is such that the corresponding relay driver output must be low to energize the associated relay, while the output is high when the relay is de-energized. For example, if the Q1 output of U35 is low, relay K1 will be energized.

4.6.4 Power-on Safeguard

A power-on safeguard circuit, made up of U29 and associate components, ensures that relays do not randomly energize upon power-up. The two AND gates, U29, make up an R-S flip-flop. Initially, the Q output of the flip-flop (pin 3 of U29) is set high upon power up. Since the OEN terminals of the relay drivers U30-U45 are held high, their outputs are disabled, and all relays remain de-energized regardless of the relay data information present at that time.

The first STROBE pulse that comes along (in order to load relay data) clears the R-S flip-flop, setting the OEN lines of U30-U45 low to enable their outputs. This action allows the relays to be controlled by the transmitted relay data information.

A hold-off period of approximately 470msec in included in the safeguard circuit to guard against premature enabling of the relays. The time constant of the hold-off period is determined by the relative values of R1 and C20.

4.6.5 Isolator Relays

Row and column isolator relays are necessary in addition to the crosspoint relays in order to ensure the integrity of low-level signal pathways (rows A, B, G, and H). Row isolator relays include K121 through K128, while column isolators are K25 through K36, and K85 through K96. The necessary isolator relay(s) are closed in addition to the selected crosspoint to complete the entire pathway. For example, if crosspoint C10 is closed, relays K34, K46, and K123 would be energized.

SECTION 5
Replaceable Parts

5.1 INTRODUCTION

This section contains a list of replaceable electrical and mechanical parts for the Model 7072, as well as a component layout drawing and schematic diagram of the matrix card.

5.2 PARTS LISTS

Electrical parts are listed in order of circuit designation in Table 5-1. Table 5-2 summarizes mechanical parts.

5.3 ORDERING INFORMATION

To place an order, or to obtain information about replacement parts, contact your Keithley representative or the factory (see the inside front cover of this manual for addresses). When ordering parts, be sure to include the following information:

1. Matrix card model number (7072)
2. Card serial number
3. Part description
4. Circuit designation, if applicable
5. Keithley part number

5.4 FACTORY SERVICE

If the matrix card is to be returned to Keithley Instruments for repair, perform the following:

1. Complete the service form located at the back of this manual, and include it with the unit.
2. Carefully pack the card in the original packing carton or the equivalent.
3. Write ATTENTION REPAIR DEPARTMENT on the shipping label. Note that it is not necessary to return the matrix mainframe with the card.

5.5 COMPONENT LAYOUT AND SCHEMATIC DIAGRAM

Figure 5-1 is the component layout for the Model 7072. Figure 5-2 shows a schematic diagram of the card on four separate sheets.

TABLE 5-1. MODEL 7072 ELECTRICAL PARTS LIST

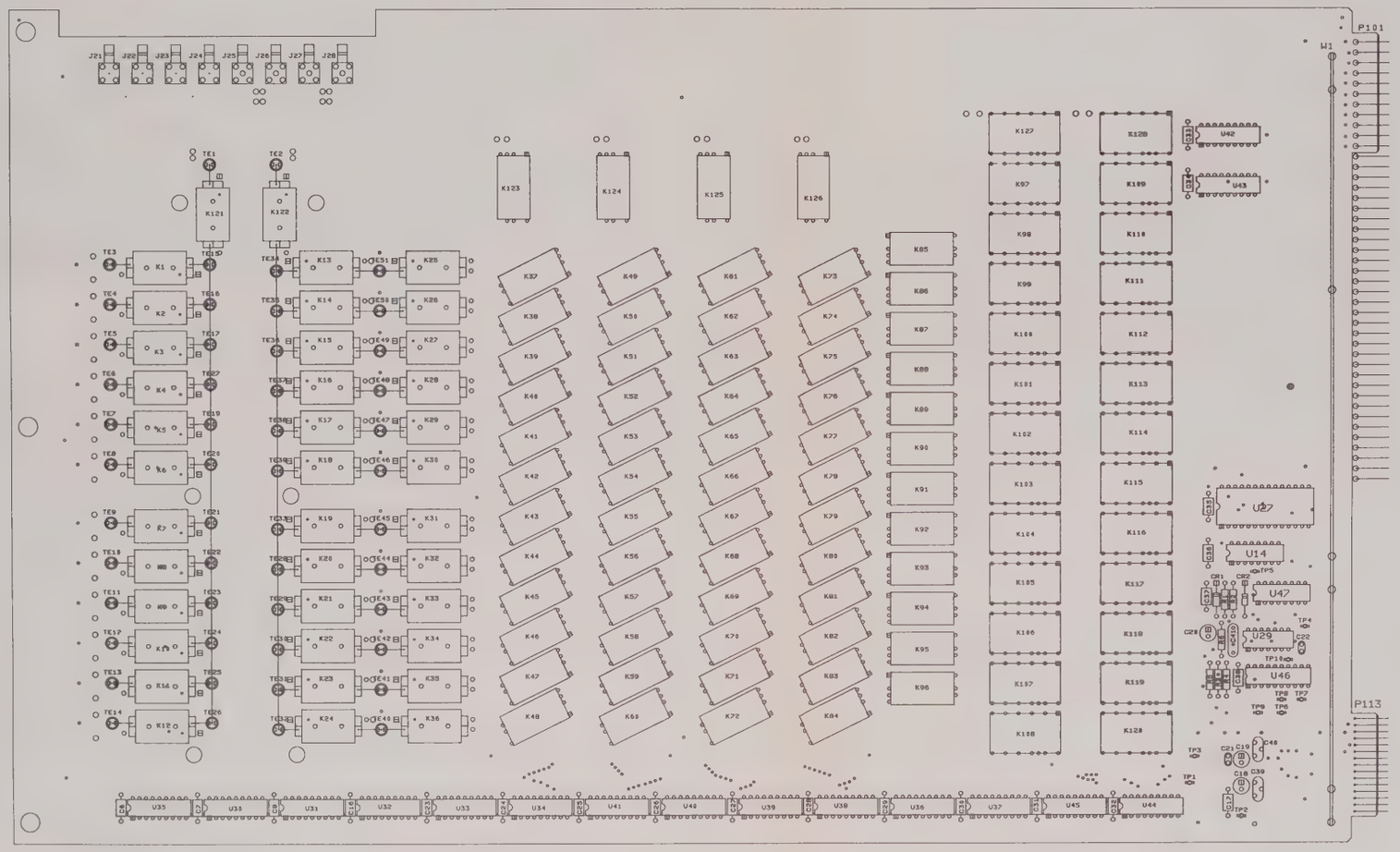
CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART NO.
C18..C20	CAP,10uF,-20+100%,25V,ALUM ELEC	C-314-10
C21,C22	CAP,.01uF,20%,50V,CERAMIC	C-237-.01
C23..C38		
C39,C40	CAP,270pF,20%,100V,CERAMIC/FERRITE	C-386-270P
C41	CAP,.01uF,10%,1000V,CERAMIC	C-64-.01
C6..C8,C16,C17,	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
CR1	DIODE,SILICON,1N4148 (DO-35)	RF-28
CR2	DIODE,SCHOTTKY,1N5711	RF-69
J1...J20	CONN,TRIAX	CS-630
J21-J28	CONN,SMB,MALE	CS-580
K1..K36,K121,	RELAY,REED	RL-106
K122		
K127,K128		
K37..K96,	RELAY,REED,(DPST)	RL-105
K97..K120,	RELAY,(4PST)	RL-104
R1	RES,47K,5%,1/4W,COMPOSITION OR FILM	R-76-47K
R2	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
R3	RES,120K,5%,1/4W,COMPOSITION OR FILM	R-76-120K
R4	RES,680,5%,1/4W,COMPOSITION OR FILM	R-76-680
R5	RES,11K,5%,1/4W,COMPOSITION OR FILM	R-76-11K
R6	RES,200,5%,1/4W,COMPOSITION OR FILM	R-76-200
TE1..TE17,	TERMINAL (TEFLON)	TE-97-1
TE19..TE51		
TP1..TP10	CONN,TEST POINT	CS-553
U14	IC,12 STAGE BINARY COUNTER,74HCT4040	IC-545
U27	IC, 64K EPROM, 2764, PROGRAMMED	7072-800
U29	IC,QUAD 2 INPUT NAND,74HCT00	IC-399
U30..U45	IC,8-BIT SERIAL-IN/LTCH DRIVE,UCN-5841A	IC-536
U46	IC,OCTAL BUFFER/LINE DRIVER,74HCT244	IC-483
U47	IC,8 BIT PARALLEL TO SERIAL,74HCT165	IC-548
W1	STIFFENER,BOARD	J-16

TABLE 5-2 MODEL 7072, MECHANICAL PARTS LIST

DESCRIPTION	KEITHLEY PART NO.
CABLE CLAMP	CC-38-4
STANDOFFS	ST-137-1
ASSEMBLY,REAR PANEL	7072-302
CABLE ASSEMBLY	CA-54-1
CAP,PROTECTIVE	CAP-30-1
FASTENER	FA-154-1
HANDLE	HH-33-1
SHIELD,REAR	7071-311
SHIELD,ROW A	7072-305
SHIELD,ROW B	7072-306
STANDOFF	7071-310
SOCKET FOR U27	SO-69

LTR.	ECO NO.	REVISION	ENG.	DATE
B	12349	RELEASED		9-14-87
C	12566	REVISED		

NO. 7072-100



NOTE:
FOR COMPONENT INFORMATION
REFER TO BILL OF MATERIAL
(7072-000-00).

7072			
MODEL	NEXT ASSEMBLY	QTY.	
USED ON			

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 1-28-88	SCALE 1:1	TITLE	COMPONENT LAYOUT, SEMICONDUCTOR CARD
KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139	XX=±.015 ANG.=±1°	DRN. CB	ENG. APPR.		
	XXX=±.005 FRAC.=±1/64	MATERIAL		D	NO. 7072-100
	SURFACE MAX. 63	FINISH			

Figure 5-1. Model 7072 Component Location Drawing, Dwg. No. 7072-100

COL 1 COL 2 COL 3 COL 4 COL 5 COL 6 COL 7 COL 8 COL 9 COL 10 COL 11 COL 12

ROW A

ROW ISOLATORS

ROW B

COLUMN ISOLATORS

+6V

K1 K2 K3 K4 K5 K6 K7 K8 K9 K10 K11 K12

K13 K14 K15 K16 K17 K18 K19 K20 K21 K22 K23 K24

K25 K26 K27 K28 K29 K30 K31 K32 K33 K34 K35 K36

K121 K122

J21 J22 J23 J24

TE1 TE2 TE3 TE4 TE5 TE6 TE7 TE8 TE9 TE10 TE11 TE12 TE13 TE14 TE15 TE16 TE17 TE19 TE20 TE21 TE22 TE23 TE24 TE25 TE26 TE27 TE28 TE29 TE30 TE31 TE32 TE33 TE34 TE35 TE36 TE37 TE38 TE39 TE40 TE41 TE42 TE43 TE44 TE45 TE46 TE47 TE48 TE49 TE50 TE51

KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

TITLE
SCHEMATIC,
SEMICONDUCTOR CARD

SIZE	MODEL	NO	ECO	REV
D	7072	7072-106	12665	C1

DRAWN	APPROVED	DATE
CB		1-15-88

PAGE 1 OF 4

Figure 5-2. Model 7072 Schematic Diagram, Dwg. No. 7072-106 (sheet 1 of 4)

COL 1 COL 2 COL 3 COL 4 COL 5 COL 6 COL 7 COL 8 COL 9 COL 10 COL 11 COL 12

ROW C ROW D ROW E ROW F

COLUMN ISOLATORS

+6V

KEITHLEY — KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139

TITLE: SCHEMATIC, SEMICONDUCTOR CARD

SIZE	MODEL	NO	ECO	REV
D	7072	7072-106	12606	C1

DRAWN: CB — APPROVED: — DATE: 1-15-88

Figure 5-2. Model 7072 Schematic Diagram, Dwg. No. 7072-106 (sheet 2 of 4)

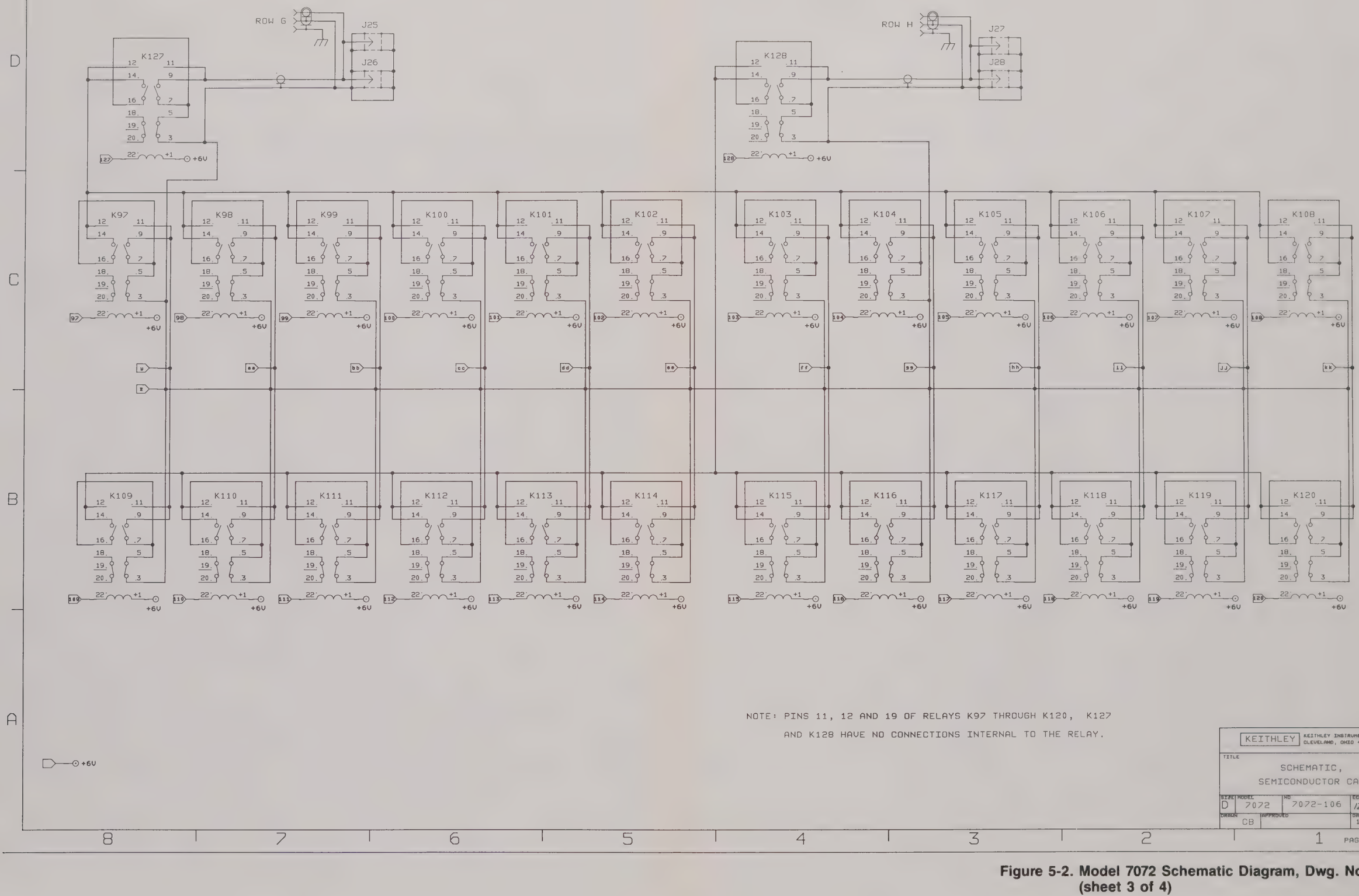


Figure 5-2. Model 7072 Schematic Diagram, Dwg. No. 7072-106 (sheet 3 of 4)

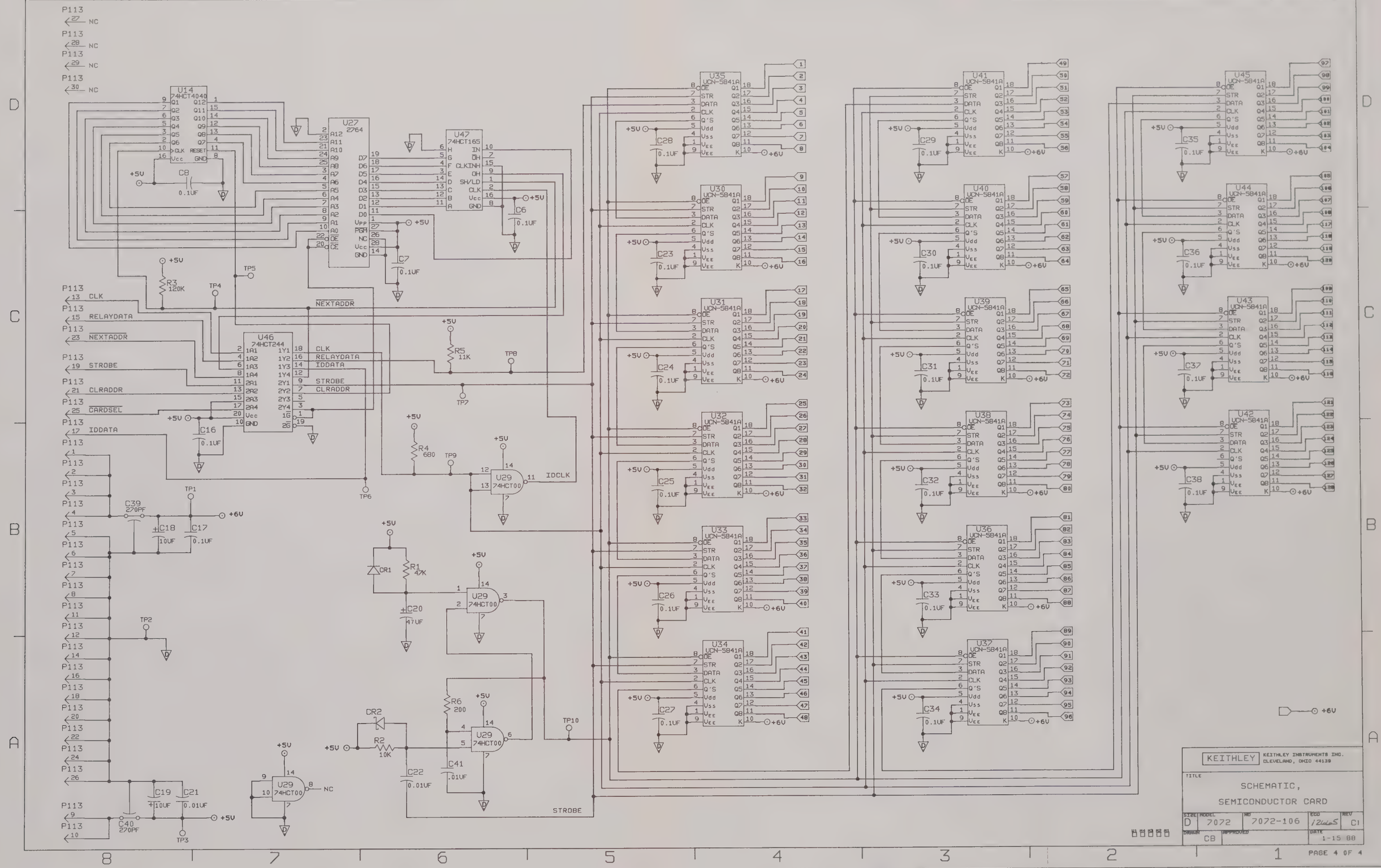


Figure 5-2. Model 7072 Schematic Diagram, Dwg. No. 7072-106 (sheet 4 of 4)

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SERVICE FORM

Model No. _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

Name _____ **Phone** _____

Company _____

Address _____

City _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.) _____

What power line voltage is used? _____ Variation? _____

Frequency? _____ Ambient Temperature? _____ °F.

Variation? _____ °F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

KEITHLEY

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GREAT BRITAIN: **Keithley Instruments, Ltd.** / 1 Boulton Road / Reading, Berkshire RG 2 ONL / 0734-861287// Telex: 847 047 / Telefax: 0734-863665
FRANCE: **Keithley Instruments SARL** / 3 Allee du 10 Rue Ambroise Croizat / B.P. 60 / 91121 Palaiseau/Cedex / 1-6-0115 155 / Telex: 600 933 / Telefax: 1-6-0117726
NETHERLANDS: **Keithley Instruments BV** / Avelingen West 49 / 4202 MS Gorinchem / P.O. Box 559 / 4200 AN Gorinchem / 01830-35333 / Telex: 24 684 / Telefax: 01830-30821
SWITZERLAND: **Keithley Instruments SA** / Kriesbachstr. 4 / 8600 Dubendorf / 01-821-9444 / Telex: 828 472 / Telefax: 0222-315366
AUSTRIA: **Keithley Instruments GesmbH** / Döblinger Haupstr. 32 / 1190 Wien / 0222-314-289 / Telex: 134 500 / Telefax: 0222-315366
ITALY: **Keithley Instruments SRL** / Viale S. Gimignano 4/A / 20146 Milano / 02-4120360 or 02-415640 / Telefax: 02-4121249

KEITHLEY

Model 7073 Addendum

The following change information is supplied as a supplement to this manual in order to provide the user with the latest improvements and corrections in the shortest possible time. It is recommended that this information be placed at the end of Section 4 of the matrix card instruction manual.

Copper cladding has been added to the rear shield of the matrix card in order to provide increased protection from static discharge. The copper shield is electrically connected to chassis ground of the matrix card by a jumper wire.

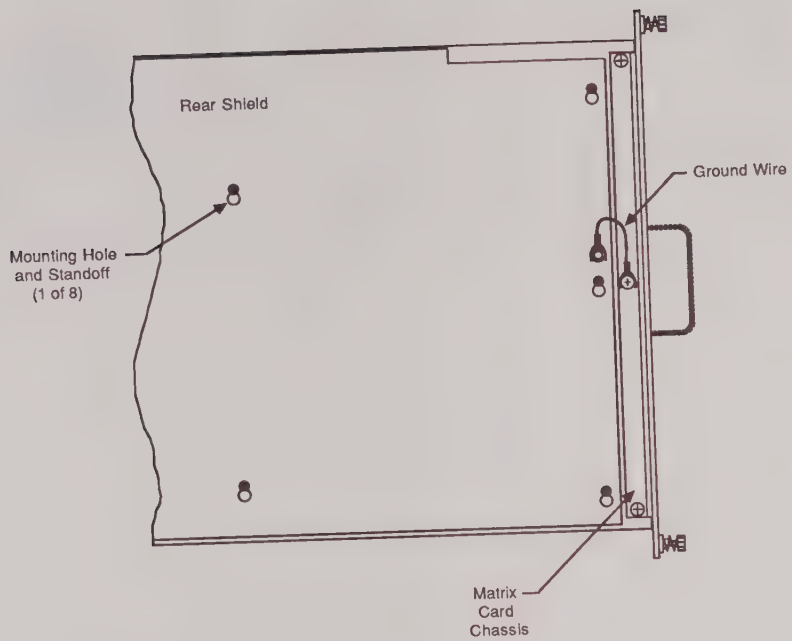
In order to service the matrix card, it may be necessary to remove the rear shield. Referring to the illustration, perform the following procedure to remove and reinstall the rear shield:

1. Disconnect the jumper wire from the matrix card chassis. The wire is secured to the matrix card chassis with a screw.
2. The rear shield is secured to the matrix card by eight standoffs. Carefully slide the rear shield upward until the eight standoffs align with the large clearance holes in the shield and remove the shield.
3. To reinstall the shield, reverse the above procedure. Make sure the metal side of the shield is facing outward.

CAUTION

Failure to observe the following precautions could result in damage not covered by the warranty:

1. **The shield must be installed such that the metal side is facing away from the matrix card. Backward installation will cause PC board connections to short out against the metal shield.**
2. **The jumper wire must be connected as shown in order to provide circuit protection from static discharge.**


Rear Shield
Ground Wire
Mounting Hole
and Standoff
(1 of 8)
Matrix
Card
Chassis

KEITHLEY

Model 7073 Coaxial Matrix Card Instruction Manual

Contains Operating and Servicing Information

Publication Date: February 1988
Document Number: 7073-901-01 Rev. B

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Keithley Instruments, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

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Instruction Manual
Model 7073
Coaxial Matrix Card

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Instruments Division
Cleveland, Ohio, U.S.A.
Document Number: 7073-901-01

SAFETY PRECAUTIONS

The following safety precautions should be observed before using the Model 7073 and the associated instruments.

This matrix card is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over this manual carefully before using the matrix card.

Exercise extreme caution when a shock hazard is present at the test circuit. User-supplied lethal voltages may be present on the card connector jacks. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS or 42.4V peak are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Do not exceed 200V between any two pins or between any pin and earth ground.

Inspect the connecting cables and test leads for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the test cables or any instruments while power is applied to the circuit under test. Turn off the power and discharge any capacitors before connecting or disconnecting cables from the matrix card.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

Do not exceed the maximum allowable input of the matrix card, as defined in the specifications and operation section of this manual.

SPECIFICATIONS

MATRIX CONFIGURATION:
8 rows by 12 columns.

CROSSPOINT CONFIGURATION:
1-pole Form A.

CONNECTOR TYPE: BNC (HI, Chassis).

MAXIMUM SIGNAL LEVEL: 200V, 1A, 30VA peak (resistive load). 200V maximum between any 2 pins or chassis.

CONTACT LIFE:
Cold Switching: 10^7 closures.
At Maximum Signal Level: 10^5 closures.

PATH RESISTANCE (per conductor): $<0.5\Omega$ initial, $<1\Omega$ at end of contact life.

CONTACT POTENTIAL: $<2\mu V$ per contact.

OFFSET CURRENT: <200pA, 10pA typical.

PATH ISOLATION*: $>10^{10}\Omega$, <0.3pF.
1MHz, 50Ω load: >80dB.
10MHz, 50Ω load: >65dB.
1MHz, 1MΩ load: >55dB.
*Path isolation specified with backplane disconnect jumpers removed.

INPUT ISOLATION: $10^9\Omega$, 220pF nominal.

INSERTION LOSS (50Ω source),
50Ω load, 10MHz: <0.5dB
1MΩ load, 1MHz: <0.2dB.

3dB BANDWIDTH, 50Ω load: 30MHz typical.

RELAY DRIVE CURRENT (per crosspoint): 20mA.

RELAY SETTLING TIME: <15ms.

ENVIRONMENT:
Operating: 0° to 50°C, up to 35°C at 70% R.H.
Storage: −25 to +65°C.

ACCESSORY SUPPLIED: Instruction manual.

ACCESSORIES AVAILABLE:
Model 7051-2: BNC to BNC Cable, 0.6m (2 ft.)
Model 7051-5: BNC to BNC Cable, 1.5m (5 ft.)
Model 7754-3: BNC to Alligator Cable, 0.9m (3 ft.)
Model 7755: 50Ω Feed-Through Terminator

Specifications subject to change without notice.

Contains information on Model 7073 features, specifications, and accessories.

SECTION 1
General Information

Details installation of the Model 7073 into the Model 707 Switching Matrix, basic matrix configurations, card connections, and also discusses operating considerations.

SECTION 2
Operation

Provides two applications for the Model 7073, including a test system for analog and/or digital devices and a test system for resistor networks.

SECTION 3
Applications

Contains performance verification procedures, principles of operation and troubleshooting information for the matrix card.

SECTION 4
Service Information

Lists replacement parts, and also includes component layout and schematic diagrams for the Model 7073.

SECTION 5
Replaceable Parts

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SECTION 1
General Information

1.1 INTRODUCTION

This section contains general information about the Model 7073 Coaxial Matrix Card and is arranged in the following manner:

1.2 Features
1.3 Warranty Information
1.4 Manual Addenda
1.5 Safety Symbols and Terms
1.6 Specifications
1.7 Unpacking and Inspection
1.8 Repacking for Shipment
1.9 Optional Accessories

1.2 FEATURES

The Model 7073 is a coaxial, one-pole 8 row × 12 column matrix card. Some of the key features include:

- Low contact potential and offset current for minimal effects on low-level signals.
- Quick-disconnect BNC connections to DUT and instrumentation.
- Backplane disconnect jumpers to isolate or connect matrix rows to the backplane of the Model 707.

1.3 WARRANTY INFORMATION

Warranty information is located on the inside front cover of this instruction manual. Should your Model 7073 require warranty service, contact the Keithley representative or authorized repair facility in your area for further information. When returning the matrix card for repair, be sure to fill out and include the service form at the back of this manual in order to provide the repair facility with the necessary information.

1.4 MANUAL ADDENDA

Any improvements or changes concerning the matrix card or manual will be explained in an addendum included with the the unit. Be sure to note these changes and incorporate them into the manual.

1.5 SAFETY SYMBOLS and TERMS

The following symbols and terms may be found on an instrument or used in this manual.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the matrix card. Such damage may invalidate the warranty.

1.6 SPECIFICATIONS

Model 7073 specifications may be found at the front of this manual. These specifications are exclusive of the matrix mainframe specifications.

1.7 UNPACKING and INSPECTION

1.7.1 Inspection for Damage

The Model 7073 is packaged in a resealable, anti-static bag to protect it from damage due to static discharge and from contamination that could degrade its performance. Before removing the card from the bag, observe to the following precautions on handling.

Handling Precautions:

1. Always grasp the card by the handle and side edges. Do not touch the edge connectors and do not touch board surfaces or components.
2. When not installed in a Model 707 mainframe, keep the card in the anti-static bag and store in the original packing carton.

After removing the card from its anti-static bag, inspect it for any obvious signs of physical damage. report any such damage to the shipping agent immediately. Save the origianl packing carton for possible reshipment.

If you are going to install the card in the Model 707 mainframe at this time, be sure to follow the additional handling precautions explained in paragraph 2.2

1.7.2 Shipping Contents

The following items are included with every Model 7073 order:

- Model 7073 Coaxial Matrix Card
- Model 7073 Instruction Manual
- Additional accessories as ordered.

1.7.3 Instruction Manual

The Model 7073 Instruction Manual is three-hole drilled so that it can be added to the three-ring binder of the Model 707 Switching Matrix Instruction Manual. After removing the plastic wrapping, place the manual in the binder after the mainframe instruction manual. Note that a manual identification tab is included and should precede the matrix card instruction manual.

If an additional instruction manual is required, order the manual package, Keithley part number 7073-901-00. The manual package includes an instruction manual and any pertinent addenda.

1.8 REPACKING FOR SHIPMENT

Should it become necessary to return the Model 7073 for repair, carefully pack the unit in its original packing carton or the equivalent, and include the following information:

- Advise as to the warranty status of the matrix card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.9 OPTIONAL ACCESSORIES

The following accessories are available for use with the Model 7073:

Model 4801—Low noise coaxial cable, 48" (1.2m) in length, with male BNC connectors on both ends.

Model 4802-10—Low noise coaxial cable, 10ft. (3m) in length, with a male BNC connector at one end and unterminated at the other end.

Model 4803—Low noise cable kit. Includes 50ft. of low noise coaxial cable, 10 male BNC connectors, and 5 female BNC chassis-mount connectors.

Model 4804—Male BNC to female triax adapter.

Model 4851—BNC shorting plug.

Model 6147—Male triax to female BNC adapter.

Model 7051-2 BNC to BNC Cable—The Model 7051-2 is a 50Ω BNC to BNC cable (RG-58C) 2ft. (0.6m) in length.

Model 7071-5 BNC to BNC Cable—The Model 7051-5 is a 50Ω BNC to BNC cable (RG-58C) 5ft. (1.5m) in length.

Model 7754-3 BNC to Alligator Cable—The Model 7754-3 is a 3ft. (0.9m) 50Ω cable (RG-58C) terminated with a BNC plug on one end and two alligator clips on the other end.

Model 7755 50Ω Feed-Through Terminator—The Model 7755 is a BNC to BNC adapter that is teminated with a 50Ω resistor. VSWR < 1.1, dc to 250MHz.

Mode CS-115—Male UHF to female BNC adapter.

SECTION 2
Operation

2.1 INTRODUCTION

This section contains information on aspects of matrix card operation and is arranged as follows:

2.2 **Handling Precautions:** Details precautions that should be observed when handling the matrix card to ensure that its performance is not degraded due to contamination.

2.3 **Card Installation and Removal:** Covers the basic procedure for installing and removing the card from the Model 707 Switching Matrix.

2.4 **Basic Matrix Configurations:** Explains some of the basic ways that a matrix can be used to source or measure. Covers single-ended switching, differential (floating) switching, sensing, and shielding.

2.5 **Connections:** Discusses methods used to connect external DUT and instrumentation to the matrix card.

2.6 **Matrix Expansion:** Discusses the various matrix configurations that are possible by using multiple cards. The significance of the backplane disconnect jumpers is covered here.

2.7 **Typical Connection Schemes:** Provides examples of external connections for single card, multiple card and multiple mainframe systems.

2.8 **Operating Considerations:** Covers key characteristics and limitations of the matrix card. Also provides recommendations for optimizing performance.

2.2 HANDLING PRECAUTIONS

To maintain high impedance isolation, care should be taken when handling the matrix card to avoid contamination from such foreign materials as body oils. Such contamination can substantially lower leakage resistances, degrading performance.

To avoid possible contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card and do not touch board surfaces or components.

CAUTION

Do not store the card by leaning it against an object (such as a wall) with its edge connectors in contact with a contaminated surface (such as the floor). The edge connectors will become contaminated. ALWAYS store the card (in its anti-static bag) in the original shipping carton.

Dirt build-up over a period of time is another possible source of contamination. To avoid this problem, operate the mainframe and matrix card only in a clean environment.

If the card should become contaminated, it should be thoroughly cleaned as explained in paragraph 4.2.

2.3 CARD INSTALLATION AND REMOVAL

Cables connected to the matrix card make it awkward to install or remove the card. Thus, it is advisable to first install the card in the Model 707 mainframe and then make connections to it. Conversely, cables should be disconnected before removing the card from the mainframe.

CAUTION

Contamination will degrade the performance of the matrix card. To avoid contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card, and do not touch the board surfaces or components.

Referring to Figure 2-1, perform the following procedure to install the Model 7073 matrix card in the Model 707:

1. Turn the Model 707 off.
2. Select a slot in the mainframe and remove the cover plate. The cover plate is fastened to the mainframe chassis with two screws. Retain the cover plate and screws for future use.
3. With the relay side of the matrix card facing towards the fan, feed the card into the slot such that the top and bottom card edges seat into the the card edge guides of the mainframe.
4. Slide the matrix card all the way into the mainframe and tighten the two spring loaded panel fastenters.
5. To remove the card from the mainframe make sure the Model 707 is off and power is removed from external circuitry. Then reverse the above procedure.

WARNING

The mounting screws must be secured to ensure a proper chassis ground connection between the card and mainframe. Failure to properly secure this ground connection may result in personal injury or death due to electric shock.

NOTE

If using the terminal blocks, leave enough slack in the external cabling so that the card can slide out far enough to gain access to the connections.

6. To remove the card from the mainframe make sure the Model 707 is off, power is removed from external circuitry, and then reverse the above procedure.

2.4 BASIC MATRIX CONFIGURATIONS

A simplified schematic of the Model 7073 8 × 12 matrix card is shown in Figure 2-2. Each of the 96 crosspoints is made up of a one-pole switch. In this simple configuration, any row can be connected to any column by closing the appropriate crosspoint switch. The columns of every Model 7073 matrix card are numbered 1 through 12. However, the actual column numbers of the matrix are determined by which mainframe slot the card is installed. For example, the columns of a matrix card installed in slot 4 of the mainframe are numbered 37 through 48. Column number assignments for all six mainframe slots are listed in Table 2-1.

Table 2-1. Column Number Assignments

7071 Card Location	Matrix Column Numbers
Slot 1	1 through 12
Slot 2	13 through 24
Slot 3	25 through 36
Slot 4	37 through 48
Slot 5	49 through 60
Slot 6	61 through 72

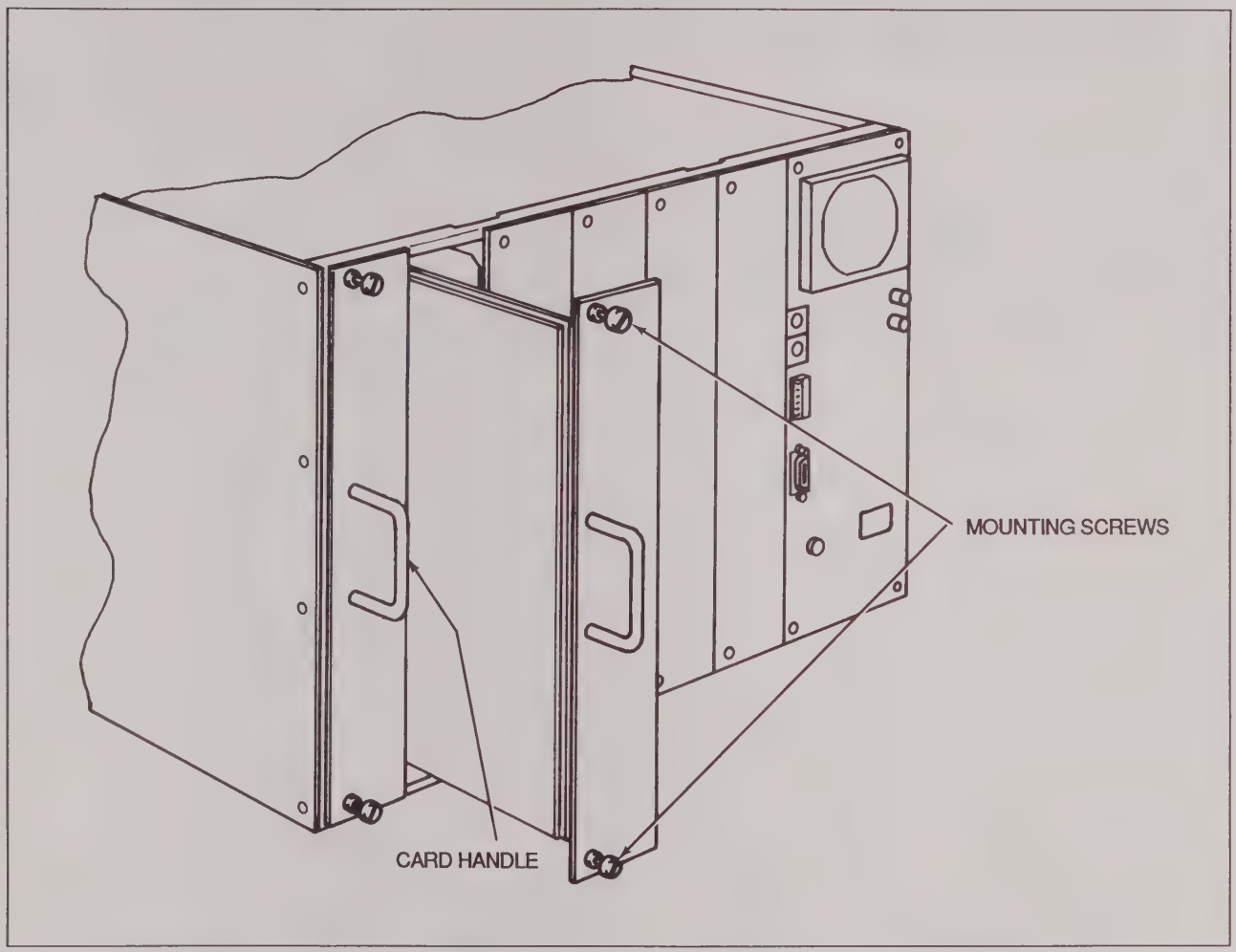


Figure 2-1. Model 7073 Installation

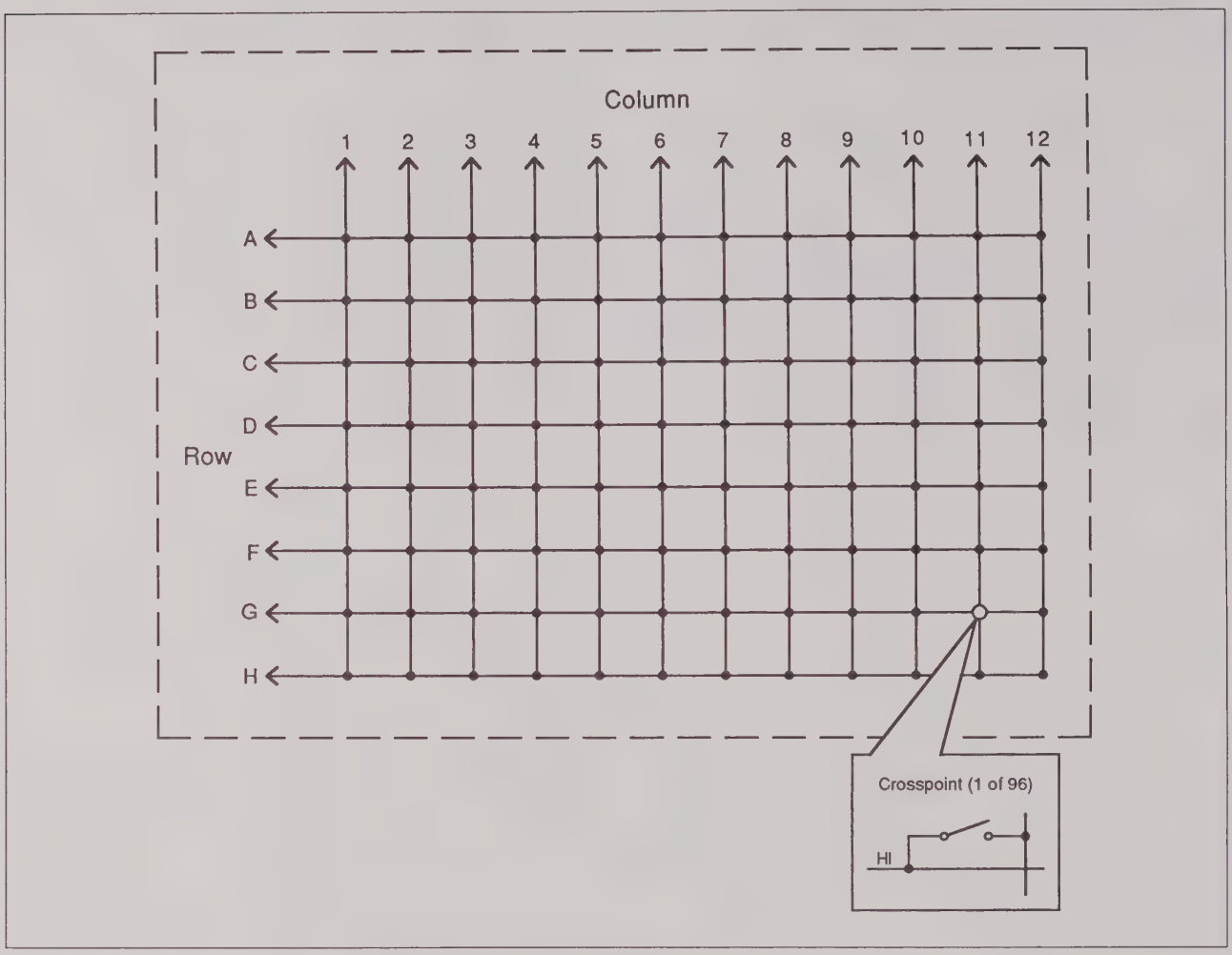


Figure 2-2. Simplified Schematic of Model 7073

2.4.1 Single-Ended Switching

In the single-ended switching configuration, the source or measure instrument is connected to the DUT through a single pathway as shown in Figure 2-3. The closure of a single crosspoint will connect an instrument to a DUT.

2.4.2 Differential Switching

The differential or floating switching configuration is shown in Figure 2-4. The advantage of using this configuration is that the terminals of the source or measure instrument are not confined to the same matrix crosspoint. Each terminal of the instrument can be connected to any of the 96 matrix crosspoints. In the illustration, matrix card low (L) is also used as a shield.

2.4.3 Sensing

Figure 2-5 shows how the matrix card can be configured to use instrumentation that have sensing capability. The main advantage of using sensing is to cancel the effects of matrix card path resistance (<1Ω) and the resistance of external cabling. Whenever path resistance is a consideration, sensing should be used. In the illustration, matrix card low is again used as a shield.

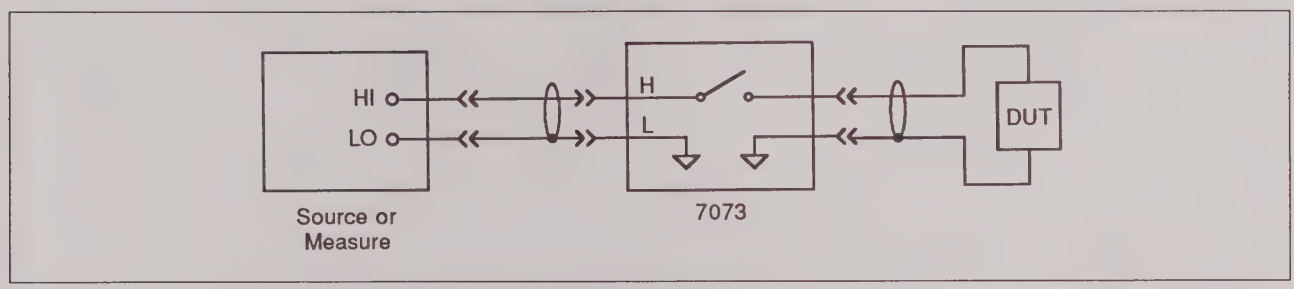


Figure 2-3. Single Ended

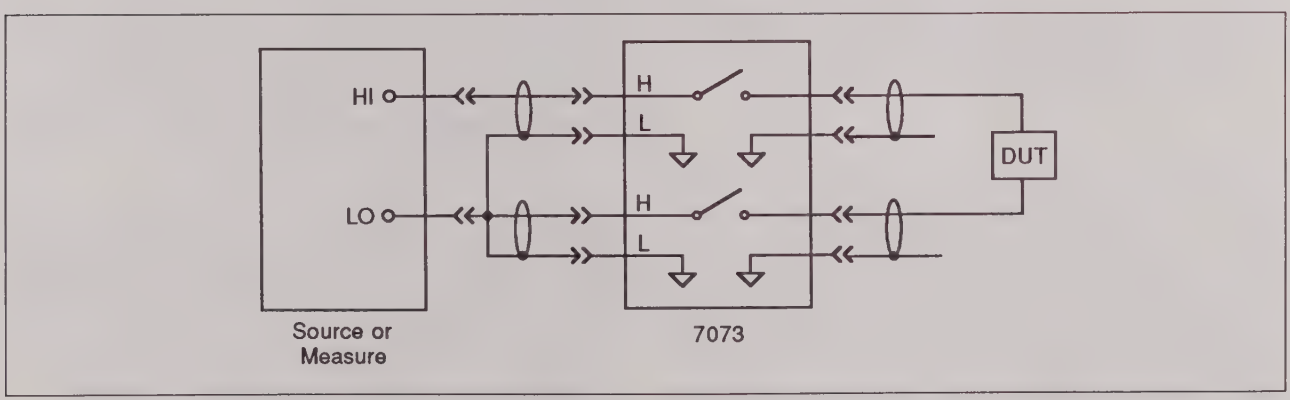


Figure 2-4. Differential (Shielded)

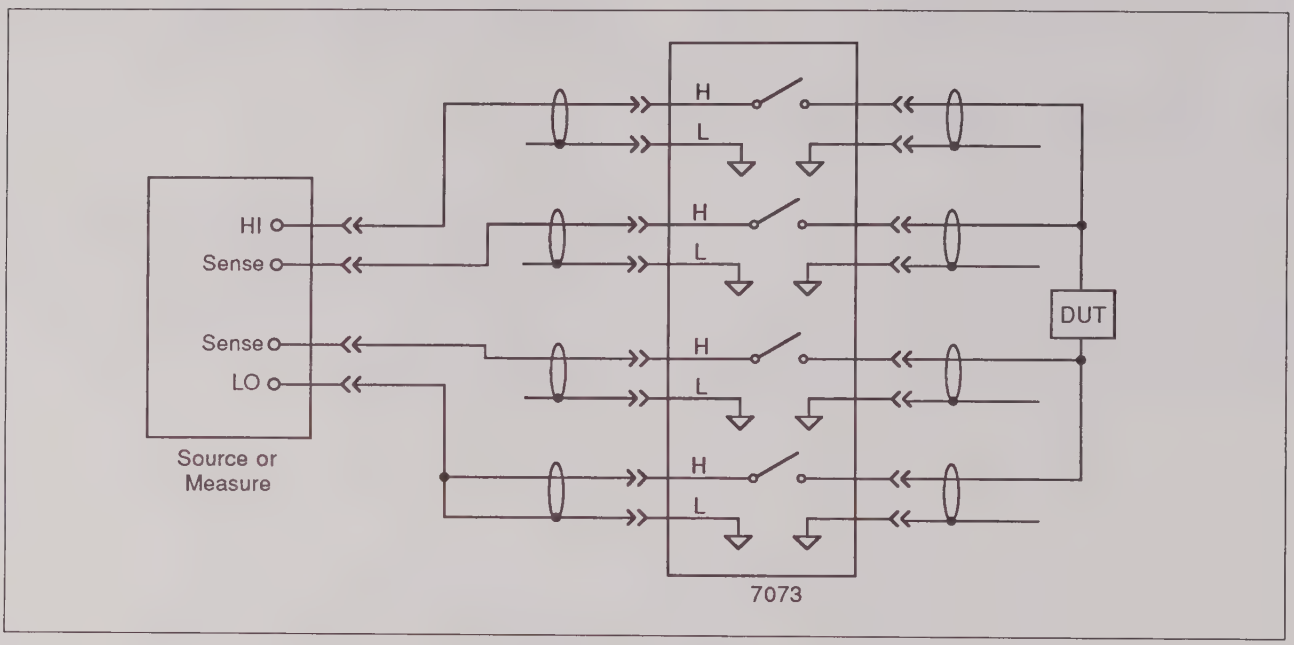


Figure 2-5. Sensing

2.5 CONNECTIONS

WARNING
To avoid injury or death, make sure all power is off and stored energy in external circuitry is discharged before making any connections to the matrix card.

External connections to the matrix card should be made after it is installed in the Model 707 mainframe. Rows and columns of the matrix card are terminated with 2-lug, female BNC connectors. Matrix card connections to instrumentation and test circuits terminated with similar type BNC connectors are easily made using BNC to BNC cables such as the ones described in paragraph 1.9. Special cables and adapters for making connections to instrumentation using different types of connectors (such as banana, triax, UHF, etc.) are available from various manufacturers. For DUTs, it may be desirable to terminate them with BNC connectors so that BNC cables can be used to connect them to the matrix card.

2.6 MATRIX CONFIGURATIONS

CAUTION
Contamination will degrade the performance (isolation properties) of the matrix card. To avoid contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card, and do not touch the board surfaces or components.

With the use of additional Model 7073 matrix cards and proper configuration of backplane disconnect jumpers, larger matricies can be configured. The following paragraph explains how to use the on-card backplane jumpers to configure a variety of matrices.

2.6.1 Backplane Disconnect Jumpers

As shipped, the Model 7073 is configured to connect its rows to the backplane of the Model 707. This allows the rows of cards installed in adjacent slots to be connected together eliminating the need for external row connections.

Each row of the Model 7073 matrix card has a moveable jumper whose position determines how (or if) that row is connected to the Model 707 backplane. The location of these jumpers on the card is shown in Figure 2-6. A simplified diagram of the Model 707 backplane is shown in Figure 2-7. The segmented line represents the backplane connections for one matrix row. As can be seen in the illustration, each slot in the empty mainframe is isolated by the open backplane connections. Row connections from one slot to an adjacent slot are accomplished through the jumpers on the Model 7073 matrix cards.

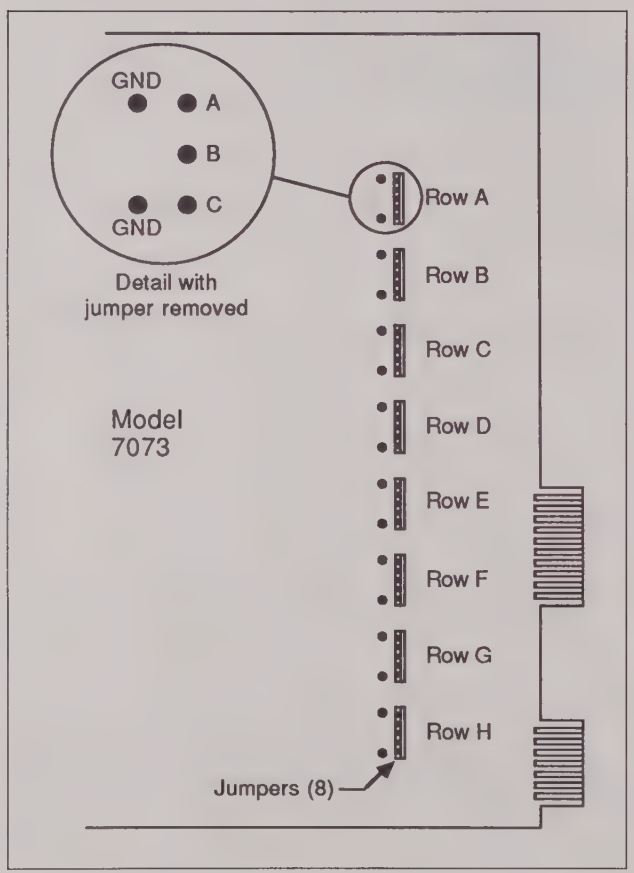


Figure 2-6. Backplane Jumper Locations (Shield Removed)

A schematic diagram showing how each row of the Model 7073 matrix card connects to the Model 707 backplane is shown in Figure 2-8. As shown, the backplane disconnect jumper is positioned to connect the matrix row to the next higher and lower mainframe slot. Positioning the jumper such that only terminals A and B are shorted, would connect the matrix row only to the next lower slot. Positioning the jumper such that only terminals B and C are shorted, would connect the matrix row only to the next higher slot. Removing the jumper would isolate the matrix row from the backplane.

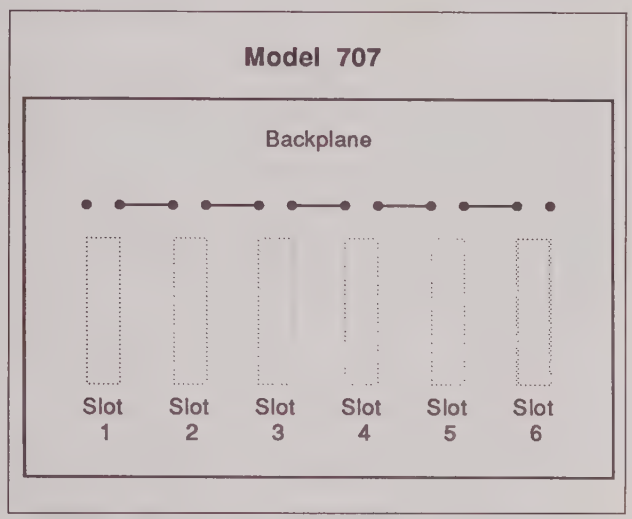


Figure 2-7. Model 707 Backplane Configuration for Model 7073 Cards

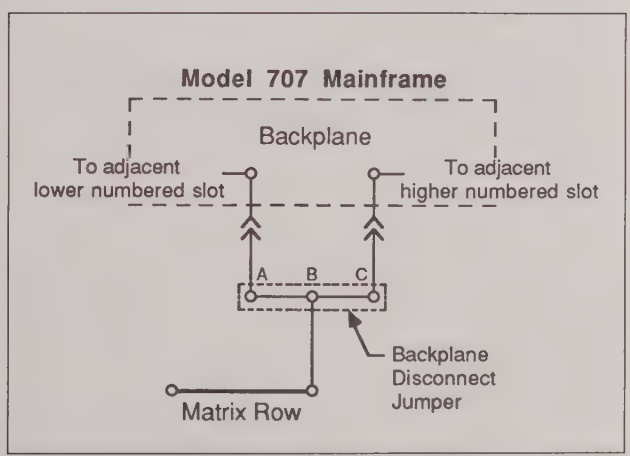


Figure 2-8. Backplane Connection Circuit (one of eight)

Each of the eight jumpers on the Model 7073 can be placed in one of four positions as shown in Figure 2-9A. With the jumper in Position 1, the matrix row makes a two-point backplane connection to adjacent slots (see Slot 2 of Figure 2-9B). The Model 7073 is shipped with the jumpers in this position. In Position 2, the matrix row makes a one-point backplane connection to the next higher numbered slot (see Slot 1 of Figure 2-9B). In Position 3, the matrix row makes a one-point backplane connection to the next lower numbered slot (see Slot 3 of Figure 2-9B). In Position 4, no connections are made to the backplane (see Slot 6 in Figure 2-9B).

In Figure 2-9B, the rows of the Model 7073s installed in slots 1, 2 and 3 are connected together, and isolated from the other slots. The rows of the Model 7073 installed in slot 6 are not connected to the backplane. Note that the cards must be installed in adjacent slots for the rows to be connected together. For example, a card installed in slot 4 will be isolated from cards in slots 1 and 2 if slot 3 is vacant or occupied by a different type card. Remember, removing a Model 7073 card from the mainframe breaks the backplane serial link.

NOTE

The Model 707 backplane used by the Model 7073 matrix card is not used by any other matrix card type (such as the Models 7071 and 7072 matrix cards). Thus, any other card types installed in the mainframe will always be isolated from Model 7073 cards.

To gain access to the backplane disconnect jumpers, remove the shield as explained in paragraph 4.7.2.

WARNING

To avoid injury (cut fingers) and contamination to the card, do not attempt to pull the jumpers off the board by hand. Instead, use a small bladed screwdriver to pry the jumpers off the board.

2.6.2 Narrow Matrix Expansion

As shipped from the factory, the jumpers on the card are positioned to connect the rows into the backplane of the Model 707 (see Figure 2-9A, Position 1). Thus, each Model 7073 card installed next to another Model 7073 in the mainframe extends the matrix by 12 columns (see Table 2-2). For example, three cards installed in slots 1, 2, and 3 of the Model 707 will result in an 8 × 36 matrix. Figure 2-10 shows three matrix cards installed in slots 1, 2, and 3. Again, cards must be installed in adjacent slots for the rows to be connected together.

Table 2-2. Narrow Matrix Expansion*

Installed Matrix Cards	Resulting Matrix
1 Card	8 × 12
2 Cards	8 × 24
3 Cards	8 × 36
4 Cards	8 × 48
5 Cards	8 × 60
6 Cards	8 × 72

*Jumpers must be in position 1 (see Figure 2-9A), and cards must be installed with no empty slots between them.

As previously mentioned, another way to break the backplane serial link is to place the matrix backplane jumpers in Positions 2, 3, or 4. With jumpers set to isolate the cards from the backplane (Position 4), six Model 7073s in the mainframe will result in six separate 8 × 12 matrices.

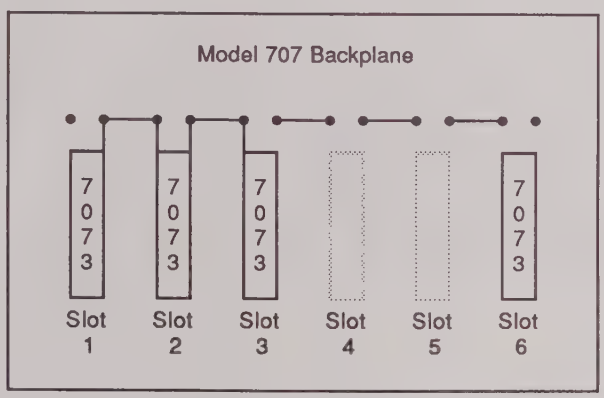
Position 1 : Makes a two point connection into the backplane. (See slot 2) Provides Backplane continuity to adjacent slots.

Position 2 : Makes a one-point backplane connection to the next higher numbered slot (See slot 1).

Position 3 : Makes a one-point backplane connection to the next lower numbered slot (See slot 3).

Position 4 : No connections made to the backplane (See slot 6). Backplane interrupted at this slot.

A.) Backplane Disconnect Jumper Positions



Jumper Positions :

Slot 1 - Card jumpers in Position 2
Slot 2 - Card jumpers in Position 1
Slot 3 - Card jumpers in Position 3
Slot 6 - Card jumpers in Position 4

B.) Example Backplane Connections

Figure 2-9. Backplane Jumpers

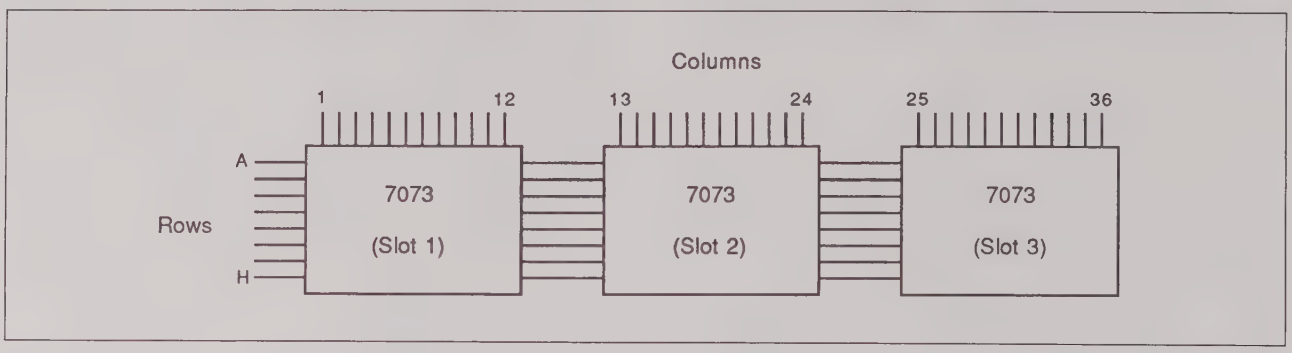


Figure 2-10. Narrow Matrix Example (8 × 36)

2.6.3 Wide Matrix Expansion

In general, wide matrices can be configured by connecting the columns of one Model 7073 card to the columns of another Model 7073 card. An example of a wide matrix (16 × 12) is shown in Figure 2-11. Note that the rows of the two cards are isolated from each other. This can be accomplished by maintaining an open slot between the two cards or by positioning their jumpers so that they are isolated from each other.

The most convenient method to connect columns of two cards together is to use 12 BNC to BNC cables (Keithley Model 7051) and 12 BNC "T" female, male, female adapters (Pomona Model 3285). Connect the "T" adapters to the 12 columns of one card, and then connect the BNC cables from the adapters to the columns of the other card. The extra BNC connector on each adapter will then allow column connection to instrumentation or DUTs.

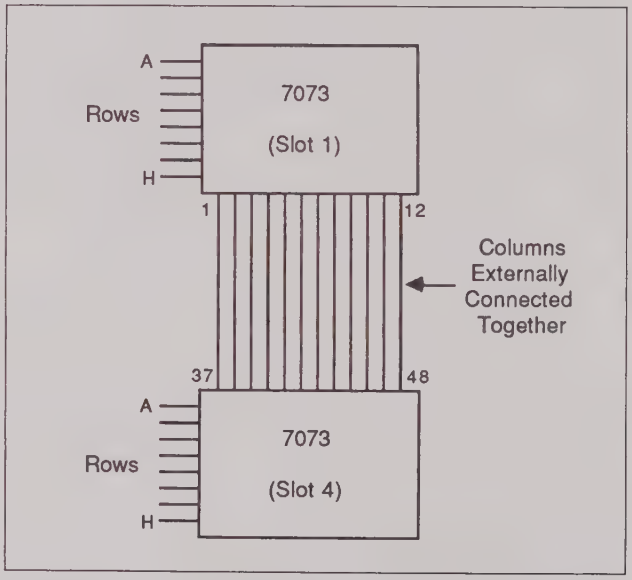


Figure 2-11. Wide Matrix Example (16 × 12)

2.6.4 Partial Matrix Implementation

A fully implemented matrix provides a relay at each potential crosspoint. For example, a fully implemented 16 × 24 matrix utilizing four Model 7073s contains 384 crosspoints. A partially implemented matrix can be obtained by removing one Model 7073 from the mainframe (see Figure 2-12). The partial matrix is still 16 × 24, but contains only 288 crosspoints. An obvious advantage of a partial matrix is that less matrix cards are needed. Another reason to use a partial matrix is to keep certain devices from being connected directly to other certain devices. For example, a source in Figure 2-12 cannot be connected to DUT #2 with one "accidental" crosspoint closure. Three specific crosspoints must be closed in order to connect a source to DUT #2.

2.6.5 Mainframe Matrix Expansion

Matricies using up to 30 Model 7073 matrix cards are possible by daisy-chaining five Model 707 mainframes together. Using 30 Model 7073 matrix cards provides 2880 crosspoints.

In general, connecting columns of a card in one mainframe to the columns of a card in another mainframe increases the the row numbers of the matrix. Connecting rows of any card in one mainframe to the rows of any other card in a second mainframe increases the column numbers of the matrix. See the Model 707 Instruction Manual for detailed information on daisy-chaining Model 707 mainframes.

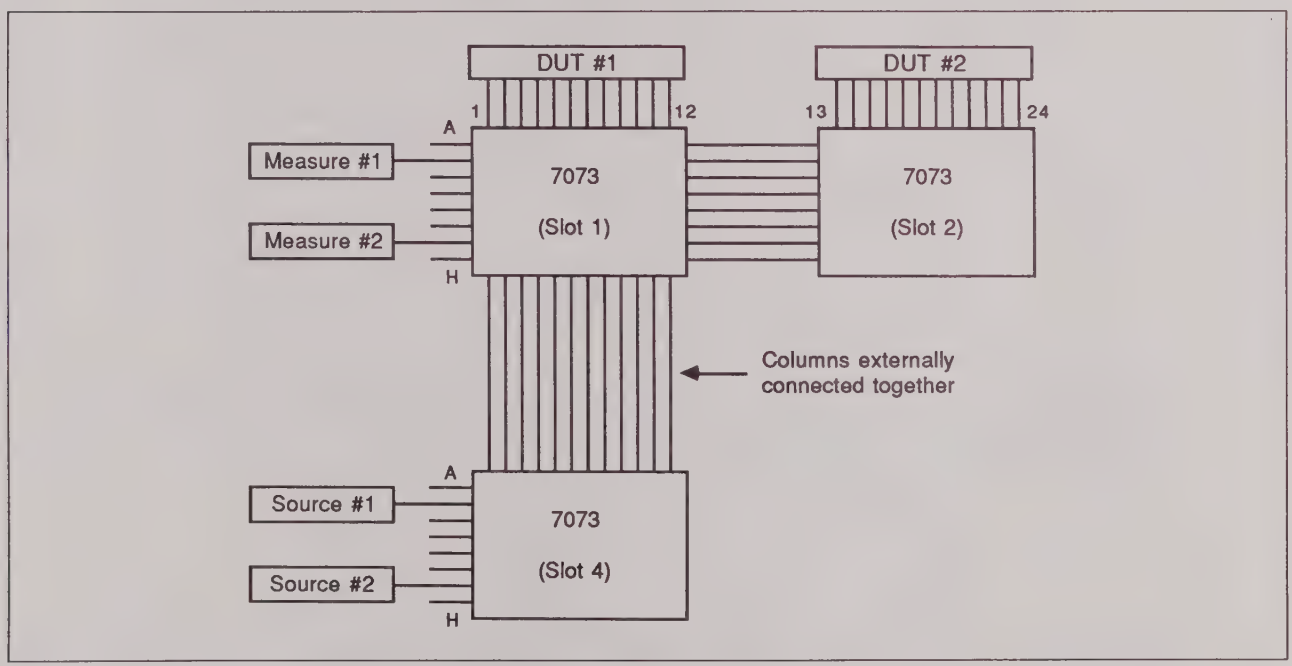


Figure 2-12. Partial Matrix Example (16 × 24)

2.7 TYPICAL CONNECTION SCHEMES

The information in this paragraph provides a typical connection scheme for single card, multiple card and multiple mainframe configurations. The examples in Figures 2-14 and 2-15 assume that the backplane disconnect jumpers of all cards are in Position 1 (rows of all cards connected together).

Figure 2-13 shows an example of how a single card system might be connected. Instruments are connected to matrix rows, and DUTs are connected to matrix columns. Note however, that since instrumentation only uses four rows in this example, the remaining four rows are used for DUTs.

Figure 2-14 shows how a multiple card system might be connected. Instruments are connected to the rows of the matrix card in slot 1, while the columns of each card are connected to the DUTs.

Figure 2-15 shows an example of how a multiple mainframe system might be connected. In this system, instrumentation and DUTs are connected to matrix card columns. Note that external cabling is needed to connect matrix rows of the master Model 707 to the matrix rows of the slave Model 707.

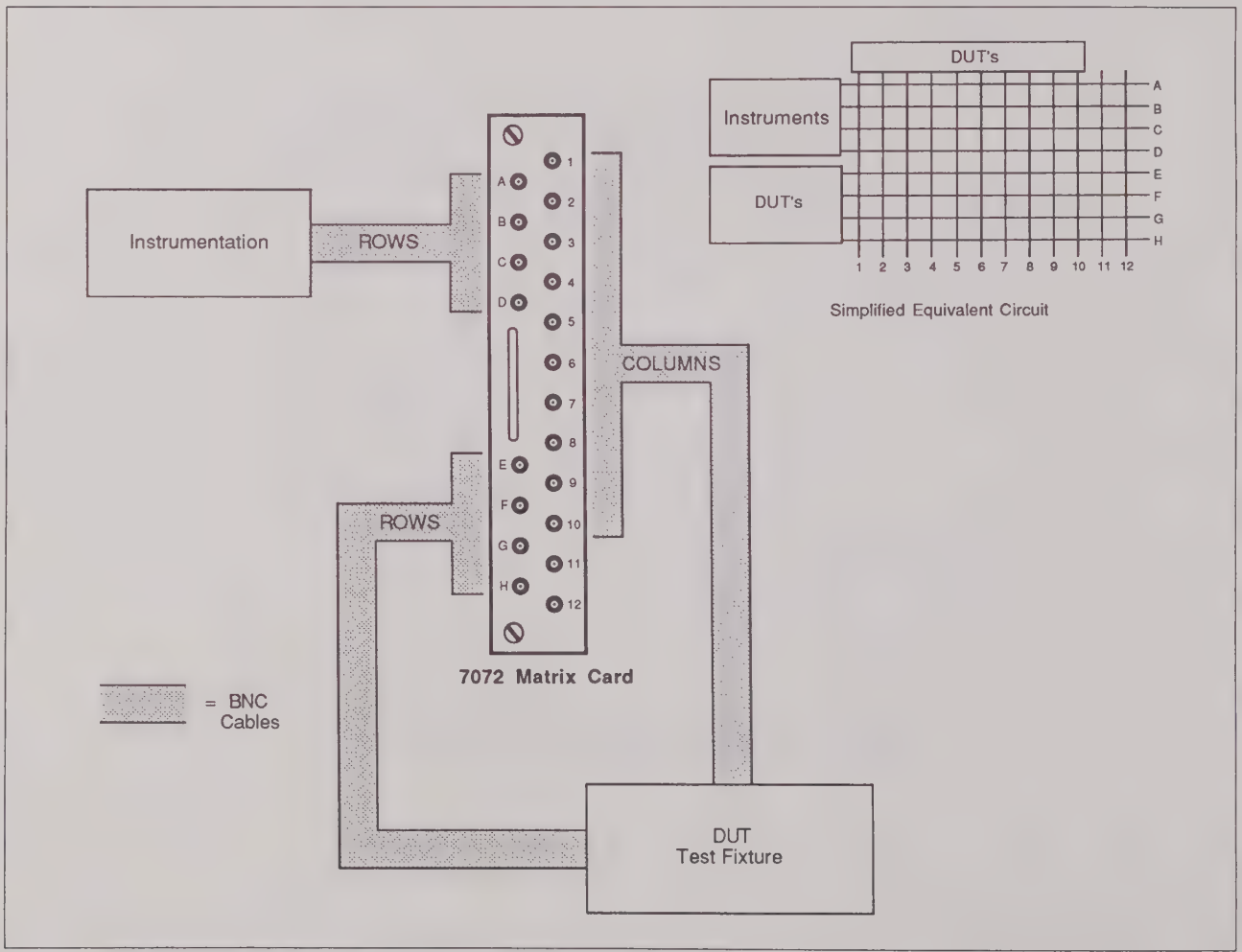


Figure 2-13. Single Card Example

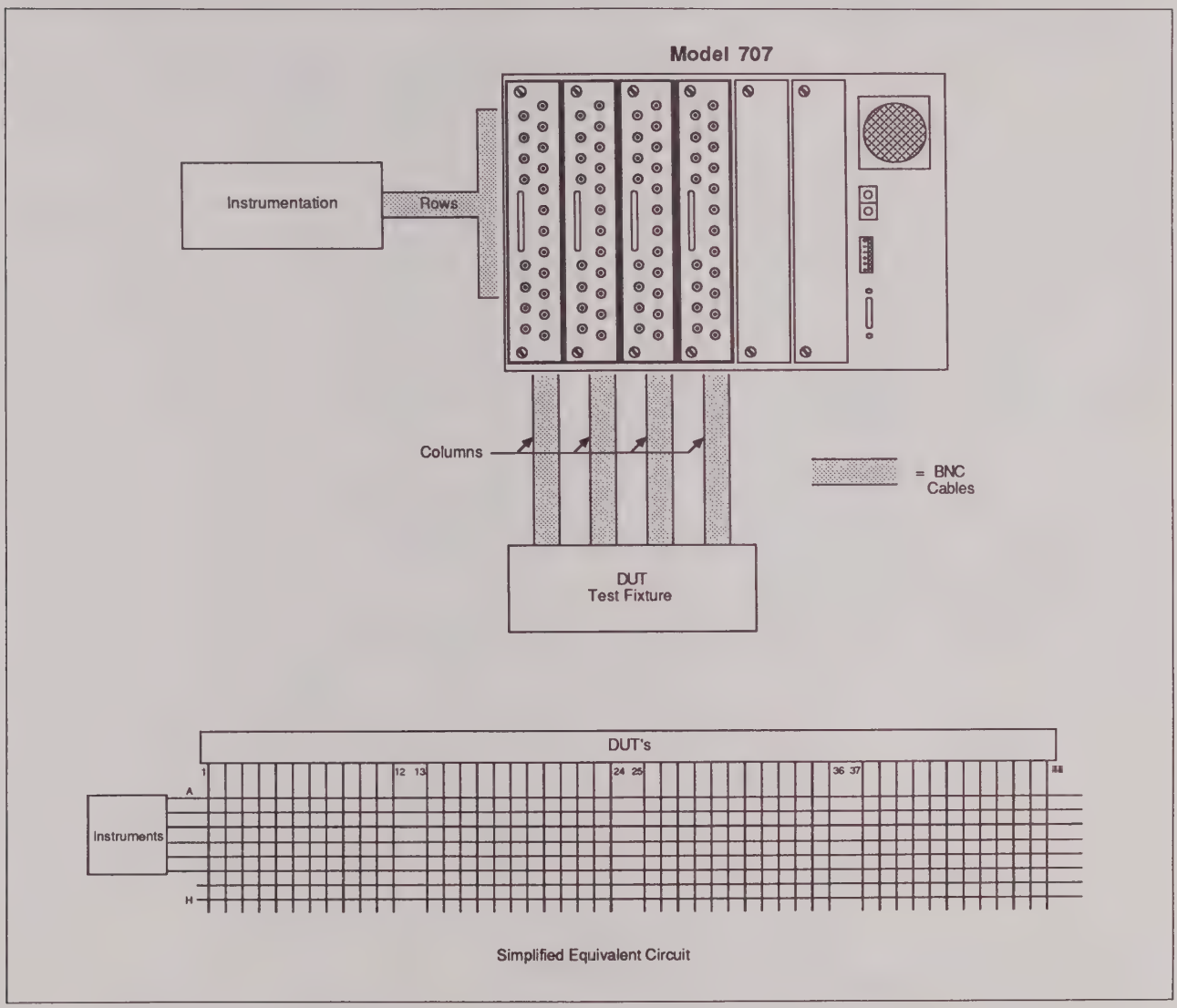


Figure 2-14. Multiple Card System Example

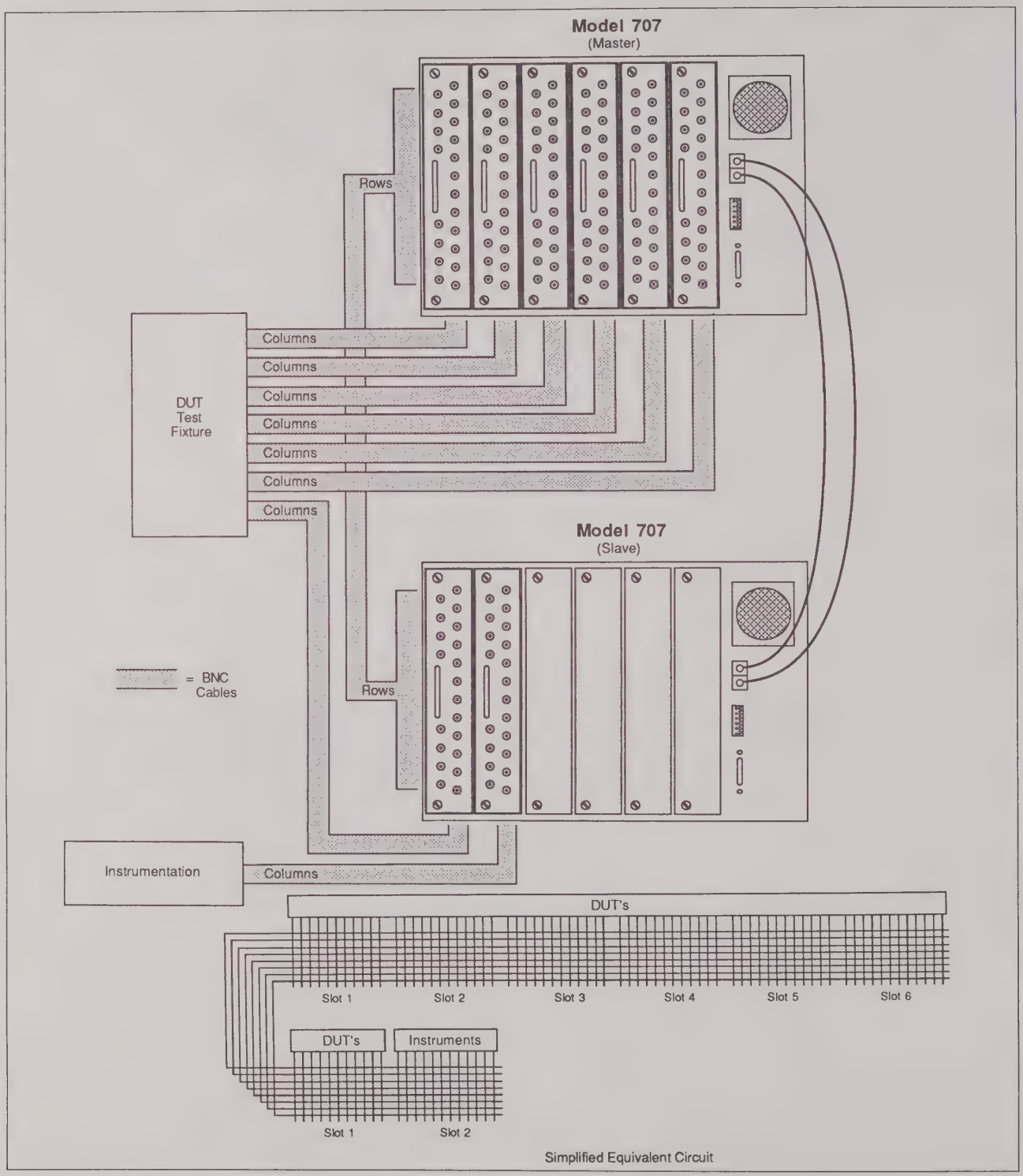


Figure 2-15. Multiple Mainframe System Example

2.8 OPERATING CONSIDERATIONS

This paragraph explains electrical characteristics and limitations of the Model 7073 matrix card. Also included are some recommendations on how to maximize the performance of the card.

Path Resistance—A matrix path is defined as the route a signal follows from row to column (or column to row) through a single crosspoint. The resistance of each matrix path is specified to be $<1\Omega$. In systems where path resistance is critical, use instrumentation that have sensing capabilites, or connect source leads and measurement leads through different pathways (4-wire Kelvin connections). If sensing cannot be done, keep external cabling as short as possible and minimize the number of connections to keep resistance to a minimum.

Contact Potential and Offset Current—Each crosspoint relay generates $<2\mu V$ of thermal EMF and must be considered in systems where low signal levels are used. Thermal EMFs can be minimized by using two adjacent paths to carry signals. Two adjacent relays (such as A1 and B2) will be at practically the same temperature resulting with the same thermal EMF level. The signal through the two crosspoints will be opposite in direction causing thermal EMFs of the two relays to cancel. Thermal EMFs caused by external circuitry can be minimized by using conductors that are made out of the same material. For example, an excellent low thermal junction is a clean, crimped copper-to-copper connection. In general, use high quality cables and connections. Finally, the thermal EMF can be measured and subtracted from the measurement. The matrix card can generate $<200pA$ of offset current (typically 10pA) and must also be considered in a system where low signal levels are used. A common source of excessive offset current is "battery affect" caused by contamination of connectors or cables.

Isolation—Matrix card path isolation is specified at $>10^{10}\Omega$ with the card disconnected from the Model 707 backplane. Each additional Model 7073 card connected through the backplane further decreases isolation. For example, two cards connected together through the backplane have better isolation than three cards connected together. Input isolation is specified at $>10^{9}\Omega$. Note that the more cards that are connected through the backplane the more this isolation specification will degrade. Thus, for maximum isolation requirements, only one Model 7073 should be used in a system. Also, note that to maintain isolation, external cables and test fixture connectors must have excellent insulators, such as Teflon® .

Insertion Loss—In a 50Ω system (source and load), sinusodial signals up to 30MHz (3dB point), and digital (squarewave) signals up to 3MHz can be effectively routed through the card. In non-50Ω systems, sinusodial signals up to 1MHz and digital signals up to 100kHz can be effectively routed through the card. For sinusodial signals in a non-50Ω system, the 3dB point can be calculated as follows:

$$f_{3dB} = \frac{1}{2\pi RC}$$

where: R = Series source resistance
C = Capacitance of the card and cables

SECTION 3
Applications

3.1 INTRODUCTION

The following applications demonstrate the versatility of using the matrix card in a test system.

3.2 ANALOG/DIGITAL DEVICE TESTING

This application demonstrates how a variety of equipment configured in a matrix can be used to perform multiple tests on analog and digital DUTs. This is a single-ended system which has all signal lows connected together (system common).

3.2.1 Test Setup

An example of a test system is shown in Figure 3-1. The DUTs shown in this system are input/output devices. For high volume testing, a fixture that uses quick-disconnect sockets for the DUT will speed up the testing process. Also, BNC connectors can be mounted on the test fixture so that BNC to BNC cables (Keithley Model 7051) can be used to connect the DUT to the matrix card.

Most of the instruments used in the system use BNC connectors making it simple to connect them to the matrix card using BNC to BNC cables. For instrumentation that uses other type of connectors, there are adapters available (some from Keithley) to convert to BNC female.

3.2.2 Test Configurations

Because of the versatility of a matrix, any instrument can be connected to any port of any DUT by simply closing the appropriate crosspoint. However, in the test system shown in Figure 3-1, the instruments are most likely to be configured as follows:

Precision Source—The Keithley Model 263 is used to source voltage or current, as needed, to the DUT. When testing DUT #1, crosspoint A1 is closed to supply a test signal to it. When testing DUTs #2, 3, and 4, crosspoints A4, A7, and A10 are closed respectively. It is recommended that a signal be delivered to each DUT only when it is being tested so as not to exceed the maximum power output of the Model 263.

Measure Voltage—In this test system, the Model 196 DMM serves as a versatile measurement tool in that it can measure the DC component at any port of any DUT, or at a source. The DMM is connected to DUT by simply closing the appropriate crosspoint of ROW B (crosspoints B1 through B12). Only one crosspoint should be closed at any one time to avoid shorting DUT ports. The DMM can be connected directly to a sourcing instrument by closing two crosspoint. For example, to connect the DMM to the Model 263, close crosspoints A1 and B1.

Source Signal—A function generator and a pulse generator will provide a wide range of AC signals needed to test DUT. While the function generator will provide the standard analog type signals (sine, square, triangle and ramp) for analog circuits, the higher speed pulse generator can be used to test both analog and digital circuits. A signal gnerator is connected to the IN port of the DUT by closing the appropriate crosspoint. For example, to connect the pulse generator to DUT #1, close crosspoint E2.

Analyze Output—The Keithley Model 775A Programmable Counter/Timer, spectrum analyzer and Keithley Model 194 High Resolution Digitizer are used to analyze the output of the DUT. These instruments are connected to the OUT port of the DUT by closing the appropriate crosspoints. For example, to connect Card 1 input of the Model 194 to DUT #1, close crosspoint G3.

Notes:

1. The Model 7073 is specified for an offset current of <200pA, but is typically much less. Unless the actual value of offset current is known, this value should be used to calculate the minimum current that can be sourced accurately. For example, if 1% error is acceptable, the lowest current that the Model 263 should source is 20nA.
2. The system is shown in a single-ended configuration (all signals referenced to system common). By using two rows to switch both signal high and low, differential (or floating) measurements can be made. A differential system is used in the next application.

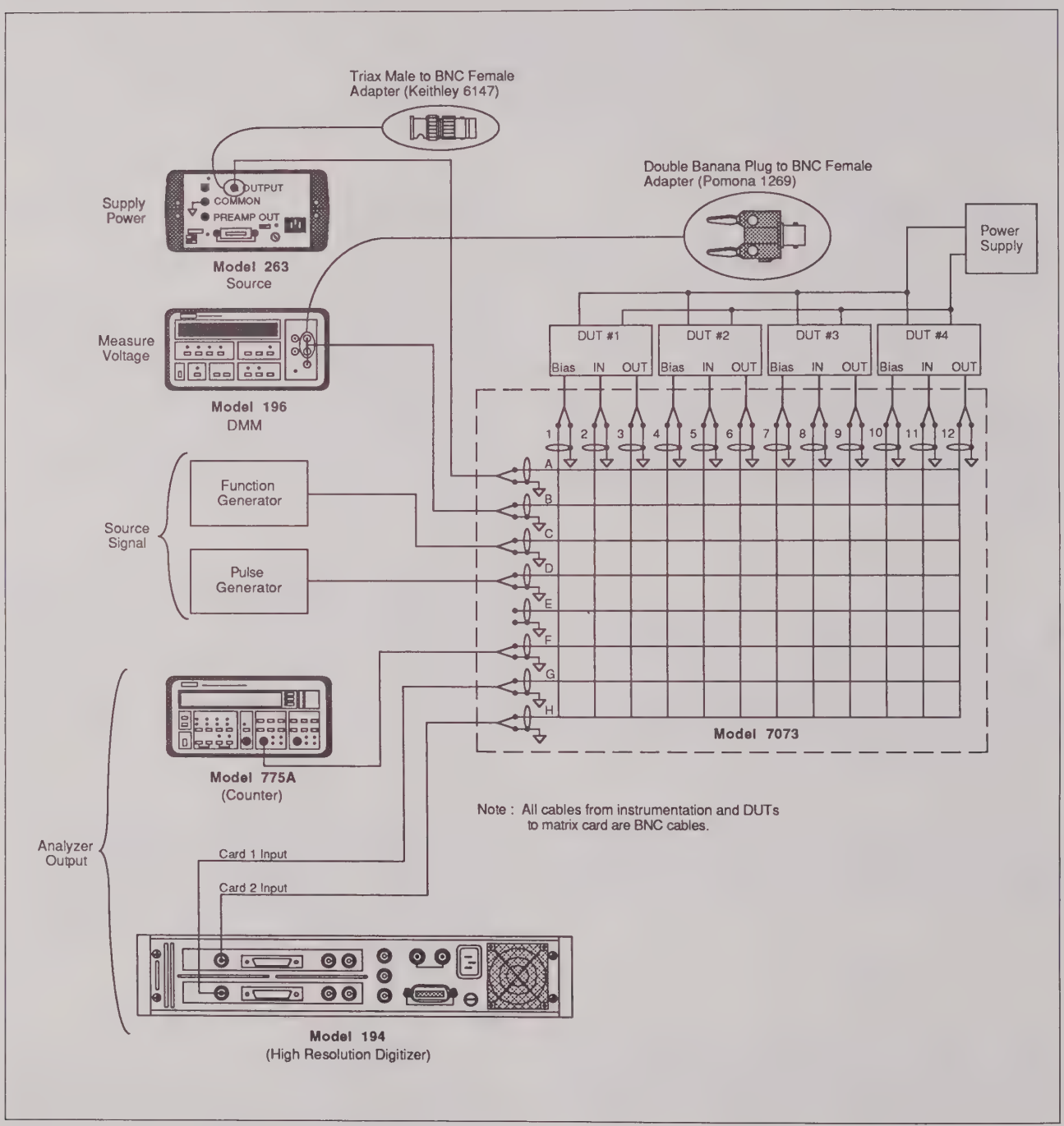


Figure 3-1. Parametric Test System

3.3 RESISTOR NETWORK TESTING

This application shows a differential (or floating) matrix system that can be used to perform a variety of tests on resistor networks. Tests include resistance measurements, capacitance or inductance measurements, and AC and DC voltage divider measurements. The test system is shown in Figure 3-2.

3.3.1 Resistance Measurements

In the ohms function, the Model 196 DMM is configured to make 2-wire ohms measurements of any or all elements of a resistor network. For example, closing crosspoints A1 and B3 will measure the resistance of R_1 and R_2 of DUT #1.

The effects of thermal EMFs generated by relay contacts and connections can be cancelled by using the offset compensated ohms feature of the Model 196. To compensate for thermal EMFs, close two crosspoints (such as A1 and B1) that will short the input of the Model 196, enable zero to cancel internal offset, and then enable offset compensation.

A consideration in 2-wire ohms measurements is the path resistance (<1Ω) and input isolation (<1GΩ) of the matrix card. The matrix card may contribute up to 0.1% error for measurements between 1kΩ and 1MΩ. For measurements between 10kΩ and 100kΩ, up to 0.01% error may be contributed by the matrix card.

To eliminate the effects of path resistance, the Model 196 can be reconfigured to make 4-terminal ohms measurements of low resistance DUTs. To do this, the matrix would have to be expanded since four pathways would be needed by the Model 196 (two paths to source and two paths to sense).

To make guarded high resistance measurements, a matrix card and ohmmeter with guard capabilities (such as the Keithley Models 7071 General Purpose Matrix Card and the Model 617 Electrometer) will be required. For guarded resistance measurements greater than 1GΩ, a matrix card with better isolation capabilities (such as the Model 7072 Semiconductor Matrix Card) should be used.

3.3.2 Voltage Divider Checks

For resistor networks that are going to be used as voltage dividers, it may be desirable to test them using AC or DC voltages that simulate actual operating conditions. This is a particularly useful test for resistor networks that have a voltage coefficient. The system in Figure 3-2 uses a Keithley Model 230 to source DC volts and a general purpose function generator to source AC volts. The Model 196 DMM is used to measure both AC (up to 100kHz) and DC volts. Note that the function generator is connected to only one path (Row F). Row E (shorted to common) is used as the return path for the generator making it a differential (floating) source.

A consideration in these checks is the affect of Model 196 input impedance on voltage measurements. The input impedance is shunted across the resistor being measured. The resultant divider resistance is the parallel combination of the resistor under test and the input impedance of the measurement instrument. As long as the input impedance is much larger than the resistor being measured, the error introduced into the measurement will be minimal.

The resistor network is tested by applying a voltage across it and measuring the voltage across each resistor element and/or across combined elements.

3.3.3 Capacitance/Inductance Measurements

In applications where capacitance or inductance is a factor, the Keithley Model 590 CV Analyzer can be used as a C-meter to measure the capacitance or inductance (-C) across each resistor element and/or across combined elements.

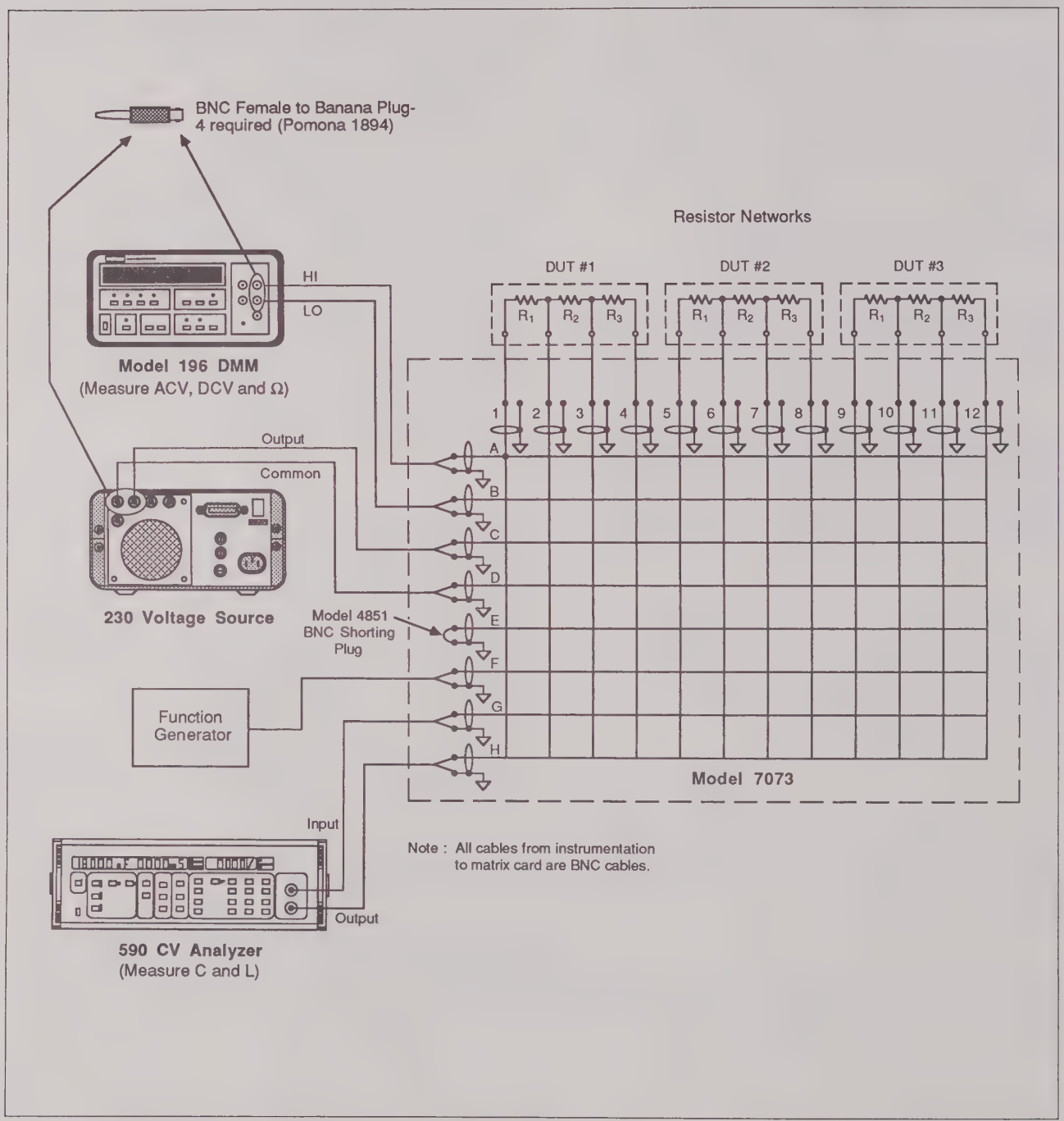


Figure 3-2. Resistor Network Testing

SECTION 4
Service Information

4.1 INTRODUCTION

This section contains information necessary to service the Model 7073 General Purpose Matrix Card and is arranged as follows:

4.2 Handling and Cleaning Precautions: Discusses handling procedures and cleaning methods for the matrix card.

4.3 Relay Test Program: Explains how to connect the matrix card to the Model 707 mainframe for the relay test program.

4.4 Performance Verification: Covers the procedures necessary to determine if the card is operating properly.

4.5 Principles of Operation: Briefly discusses circuit operation.

4.6 Special Handling of Static-Sensitive Devices: Reviews precautions necessary when handling static-sensitive devices.

4.7 Troubleshooting: Presents some troubleshooting tips for the matrix card.

4.2 HANDLING AND CLEANING PRECAUTIONS

Because of the high impedance circuits on the Model 7073, care should be taken when handling or servicing the card to prevent possible contamination, which could degrade performance. The following precautions should be taken when handling the matrix card.

1. Do not store or operate the card in an environment where dust could settle on the circuit board. Use dry nitrogen gas to clean dust off the card if necessary.
2. Handle the card only by the handle and side edges. Do not touch any board surfaces or components associated with the repair. When servicing the card, wear clean, white cotton gloves.
3. If making solder repairs on the circuit board, use a flux that is rosin RMA based. Remove the flux from these areas when the repair is complete. Use Freon® TMS or TE, or the equivalent along with plenty of clean cotton swabs to remove the flux. Take care not to spread the flux to other areas of the circuit board. Once the flux has been removed, swab only the repaired area with methanol, then blow dry the board with dry nitrogen gas.
4. After cleaning, the card should be placed in a 50°C low humidity environment for several hours.

4.3 RELAY TEST PROGRAM SETUP

The Model 707 comes equipped with a test program on disk that will test all relays of Model 7073s installed in the mainframe. The test program will flag any relay that fails to close when energized or open when de-energized. Instructions for using the test program with an IBM PC or XT, or HP 300 series computer are contained in the Model 707 Instruction Manual.

Perform the following steps to configure the Model 7073 for relay testing:

1. Remove the relay test terminal block from the rear panel of the Model 707. This is a quick-disconnect terminal block and simply pulls off the rear panel terminal strip.
2. Connect the relay test terminal block to rows A and B of any Model 7073 card installed in the mainframe as shown in Figure 4-1. Note that terminals 5 and 6 of the relay test terminal block must be shorted together.
3. Re-install the relay test terminal block into the rear panel of the Model 707 mainframe.

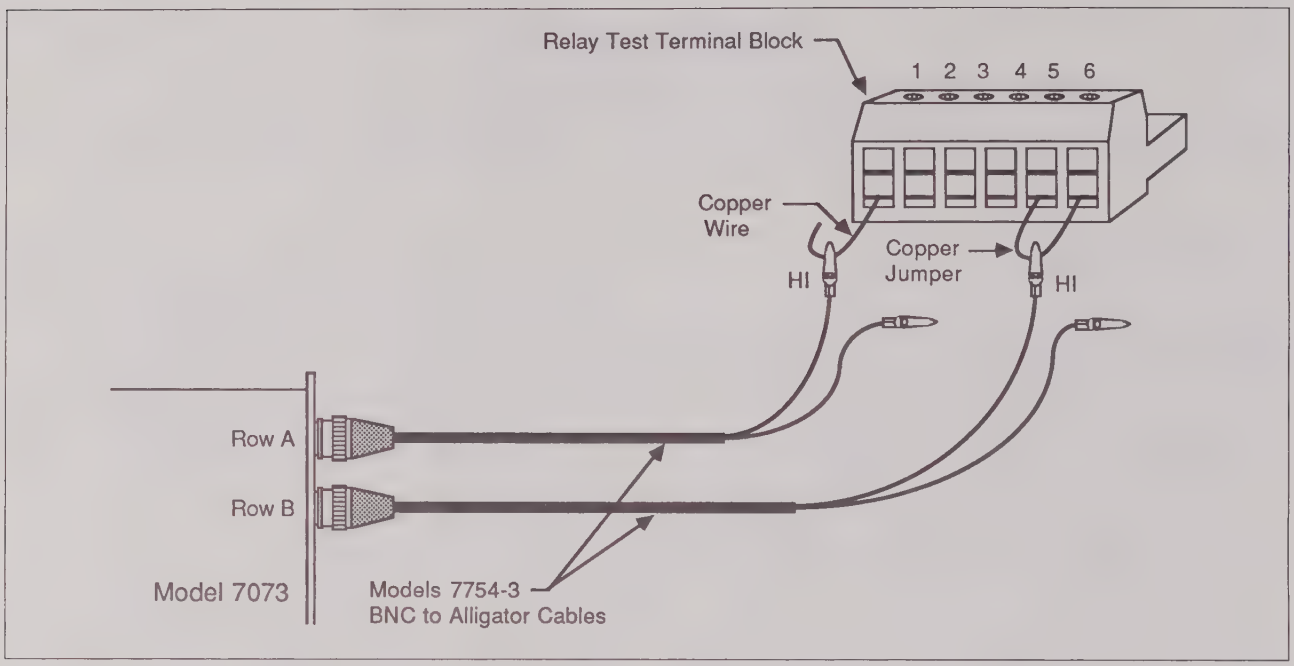


Figure 4-1. Relay Test Setup

4.4 PERFORMANCE VERIFICATION

The following paragraphs discuss performance verification procedures for the Model 7073, including path resistance, offset current, contact potential, and isolation.

The procedures in this section are rather lengthy due to the large number of row and column combinations that are checked. As an alternative to this extensive testing, it may be desirable to check only those paths that are going to be used, or those that are suspected of being faulty.

The performance verification procedures must be performed with only one matrix card (the one being checked) installed in the Model 707 mainframe. Also, the Model 707 must not be daisy-chained to another Model 707.

CAUTION

Contamination will degrade the performance of the matrix card. To avoid contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card, and do not touch the board surfaces or components.

NOTE

Failure of any performance verification test may indictate that the matrix card is contaminated. See paragraph 4.2 to clean the card. If the test still fails after cleaning, then try cleaning the backplane (see the Model 707 Instruction Manual).

4.4.1 Environmental Conditions

All verification measurements should be made at an ambient temperature between 18° and 28°C, and at a relative humidity of less than 70%.

4.4.2 Recommended Equipment

Table 4-1 summarizes the equipment necessary for performance verification, along with the application for each unit.

NOTE

Do not use the Model 7070 Universal Adapter Card as an extender card to verify performance of the Model 7073. The Model 7073 must be installed in the Model 707 mainframe.

Table 4-1. Verification Equipment

Description	Model	Specifications	Application
DMM	Keithley 196	300Ω; 0.01%	Path resistance
Electrometer w/voltage source	Keithley 617	10pA, 100pA; 1.6% 100V source; 0.2%	Offset current isolation
Nanovoltmeter	Keithley 181	2mV; 0.015%	Contact potential
Triax cable (unterminated)	Keithley 7025	—	Offset current isolation
Binding post to BNC male adapters (2)	Pomona 3430	—	Path resistance isolation
Female triax to male BNC adapter	Keithley 4804	—	Offset current path isolation
BNC female to triax male adapter	Keithley 6147	—	Input isolation
Double binding posts to BNC male adapter	Pomona 1296	—	Input isolation

4.4.3 Path Resistance Tests

Referring to Figure 4-2, perform the following steps to verify that the contact of each relay is closing properly and that the resistance is within specification.

1. Turn the Model 707 off if it is on.
2. Install the Model 7073 in slot 1 of the Model 707.
3. Set the Model 196 to the 300Ω range and connect four test leads to the OHMS and OHMS SENSE input.
4. Short the four test leads together and zero the Model 196. Leave zero enabled for the entire test.
5. Connect the Model 196 to the matrix card as shown in Figure 4-2 and turn on the Model 707.
6. Program the Model 707 to close crosspoint A1 (ROW A, COLUMN 1), and verify that the resistance of this path is <1Ω.
7. Open crosspoint A1, and connect the OHMS LO and OHMS SENSE LO test leads to ROW B.
8. Close crosspoint B1 and verify that the resistance of this path is <1Ω.
9. Repeat the basic procedure of steps 7 and 8 to check the path resistance through crosspoints C1, D1, E1, F1, G1 and H1.
10. Connect the OHMS SENSE HI and OHMS HI test leads to COLUMN 2 and check that the path resistance through crosspoints A2 through H2 is <1Ω.
11. Repeat the basic procedure of connecting the test leads to the appropriate row and column, and check the rest of the matrix crosspoints.

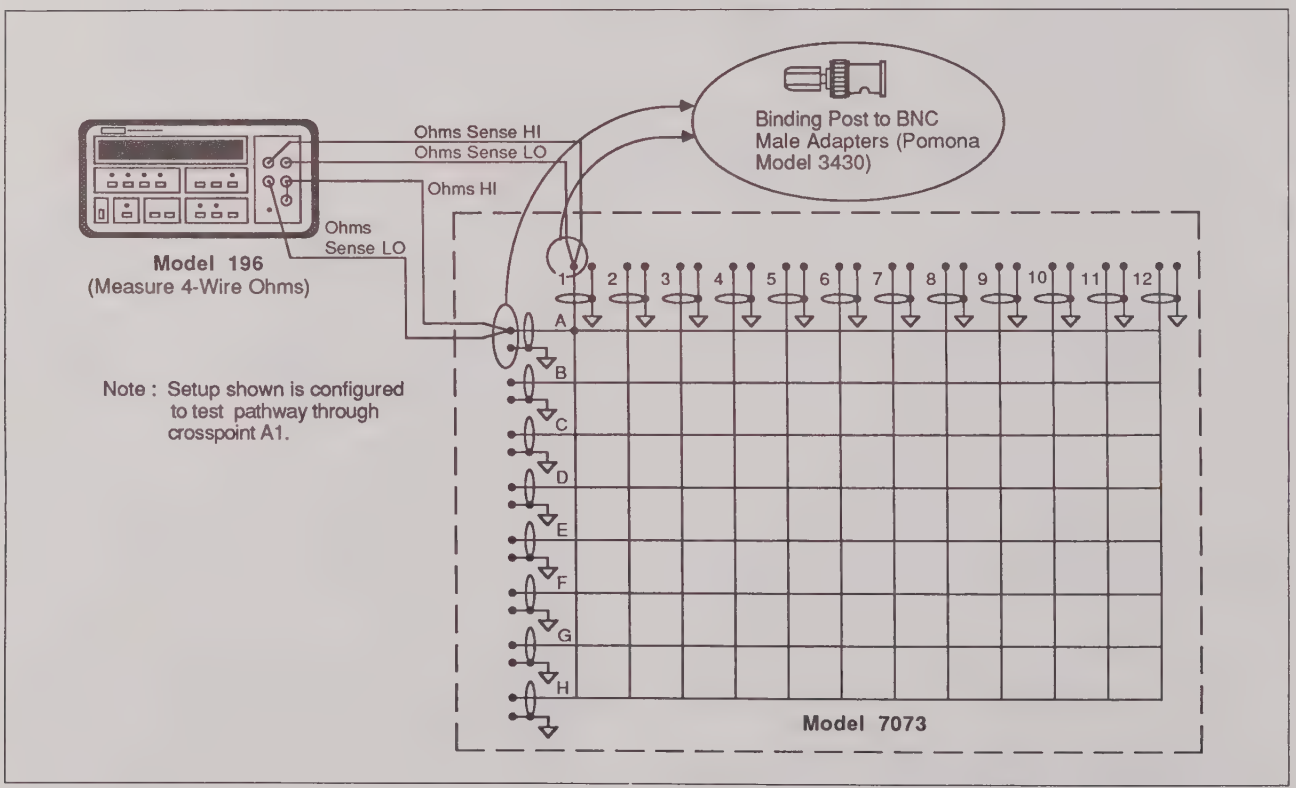


Figure 4-2. Path Resistance Testing

4.4.4 Offset Current Tests

These tests check leakage current between HI (signal high) and chassis (signal low). In general, these tests are performed by simply measuring the leakage current with a picoammeter. In the following procedure, the Keithley Model 617 is used to measure leakage current.

Referring to Figure 4-3, perform the following procedure to check offset current:

1. Turn the Model 707 off if it is on.
2. Install the matrix card in slot 1 of the Model 707.
3. On the Model 617, select the 200pA range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.
4. Connect the Model 617 to ROW A of the Model 7073 matrix card as shown in Figure 4-3.
5. Turn on the Model 707.
6. Program the Model 707 to close crosspoint A1.
7. On the Model 617, disable zero check and verify that it is <200pA. This measurement is the leakage current of the pathway.
8. On the Model 617, enable zero check and on the Model 707, open crosspoint A1.
9. Repeat the basic procedure in steps 6 through 8 to check the rest of the pathways (crosspoints A2 through A12) of the row.
10. Connect the Model 617 to ROW B of the matrix card and repeat the basic procedure in steps 6 through 8 to check crosspoints B1 through B12.
11. Repeat the above basic procedure for the remaining rows (ROWS C through H).

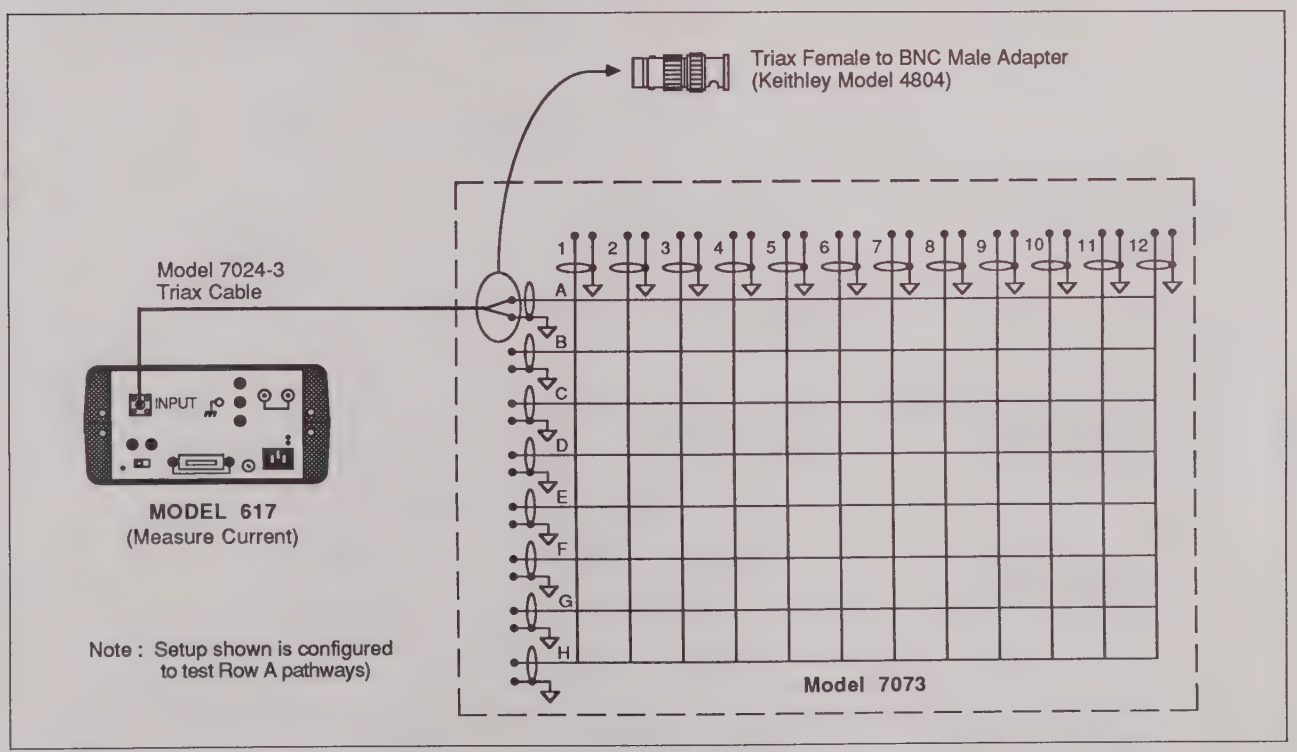


Figure 4-3. Offset Current Testing

4.4.5 Contact Potential Tests

These tests check the EMF generated by each relay contact pair (H and L) for each pathway. The tests simply consist of using a nanovoltmeter (Model 181) to measure the contact potential.

Referring to Figure 4-4, perform the following procedure to check contact potential of each path:

1. Turn the Model 707 off if it is on.
2. Install the Model 7073 in slot 1 of the Model 707.
3. Set the Model 181 to the 2mV range, short the input leads and press ZERO to null out internal offset. Leave zero enabled for the entire procedure.
4. Connect the Model 181 to the matrix card as shown in Figure 4-4 and turn on the Model 707. Notice that the copper wire is inserted into the BNC connector center conductor.

CAUTION

To prevent damage to the BNC connectors on the matrix card, do not insert a wire larger than #17 gage into the center conductors.

5. Program the Model 707 to close crosspoint A1 (ROW A, COLUMN 1), and verify that the contact potential of this path is $<2\mu V$.
6. Open crosspoint A1, and connect the LO of the Model 181 to ROW B.
7. Close crosspoint B1 and verify that the contact potential of this path is $<2\mu V$.
8. Repeat the basic procedure of steps 6 and 7 to check contact potential through crosspoints C1, D1, E1, F1, G1 and H1.
9. Connect HI of the Model 181 to COLUMN 2 and check that contact potential through crosspoints A2 through H2 is $<2\mu V$.
10. Repeat the basic procedure of connecting the test leads to the appropriate row and column and check the rest of the matrix crosspoints.

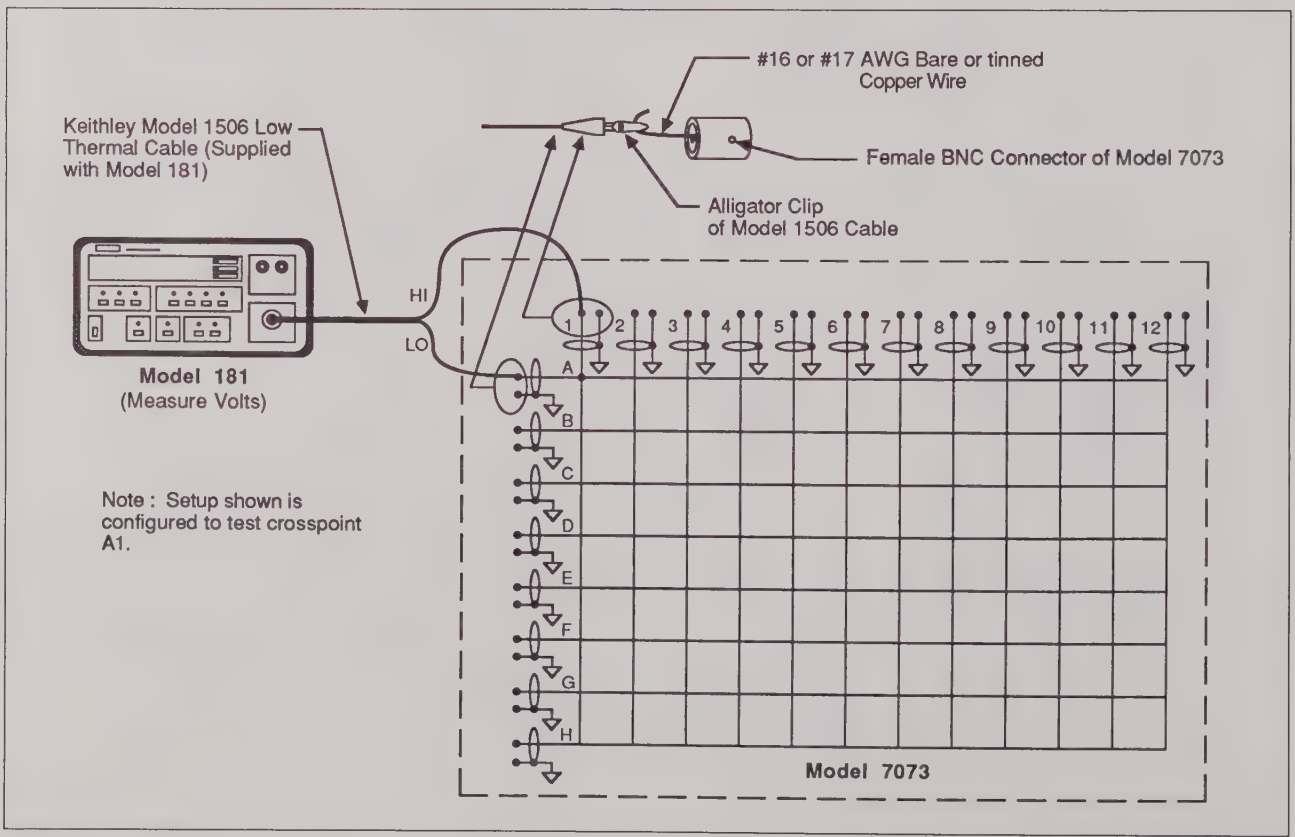


Figure 4-4. Contact Potential Testings

4.4.6 Path Isolation Tests

These tests check the leakage resistance (isolation) between adjacent paths. A path is defined as the circuit from a row to a column that results by closing a particular crosspoint.

Referring to Figure 4-5, perform the following procedure to check path isolation:

1. Turn the Model 707 off if it is on.
2. On the matrix card, remove all eight backplane disconnect jumpers in order to isolate the card from the backplane of the Model 707.
3. Install the matrix card in slot 1 of the Model 707.
4. On the Model 617, select the 2kΩ range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.
5. Connect the Model 617 to the matrix card as shown in Figure 4-5.
6. On the Model 617, select the 20GΩ range.
7. Turn on the Model 707, and program it to close crosspoints A1 (ROW A, COLUMN 1) and B2 (ROW B, COLUMN 2).
8. On the Model 617, disable zero check.
9. After allowing the reading on the Model 617 to settle, verify that it is >10GΩ. This measurement is the leakage resistance (isolation) between ROW A, COLUMN 1 and ROW B, COLUMN 2.
10. On the Model 617, enable zero check.
11. Move both leads of the Model 617 down one row such that they are connected to ROWs B and C.
12. Program the Model 707 to close crosspoints B2 and C3.
13. On the Model 617, disable zero check.
14. After allowing the reading on the Model 617 to settle, verify that it is >10GΩ.
15. Using Table 4-2 as a guide, repeat the basic procedure of steps 10 through 14 for the rest of the path pairs (test numbers 3 through 11 in the table).
16. Turn off the Model 707, remove the matrix card, and re-install the backplane disconnect jumpers.

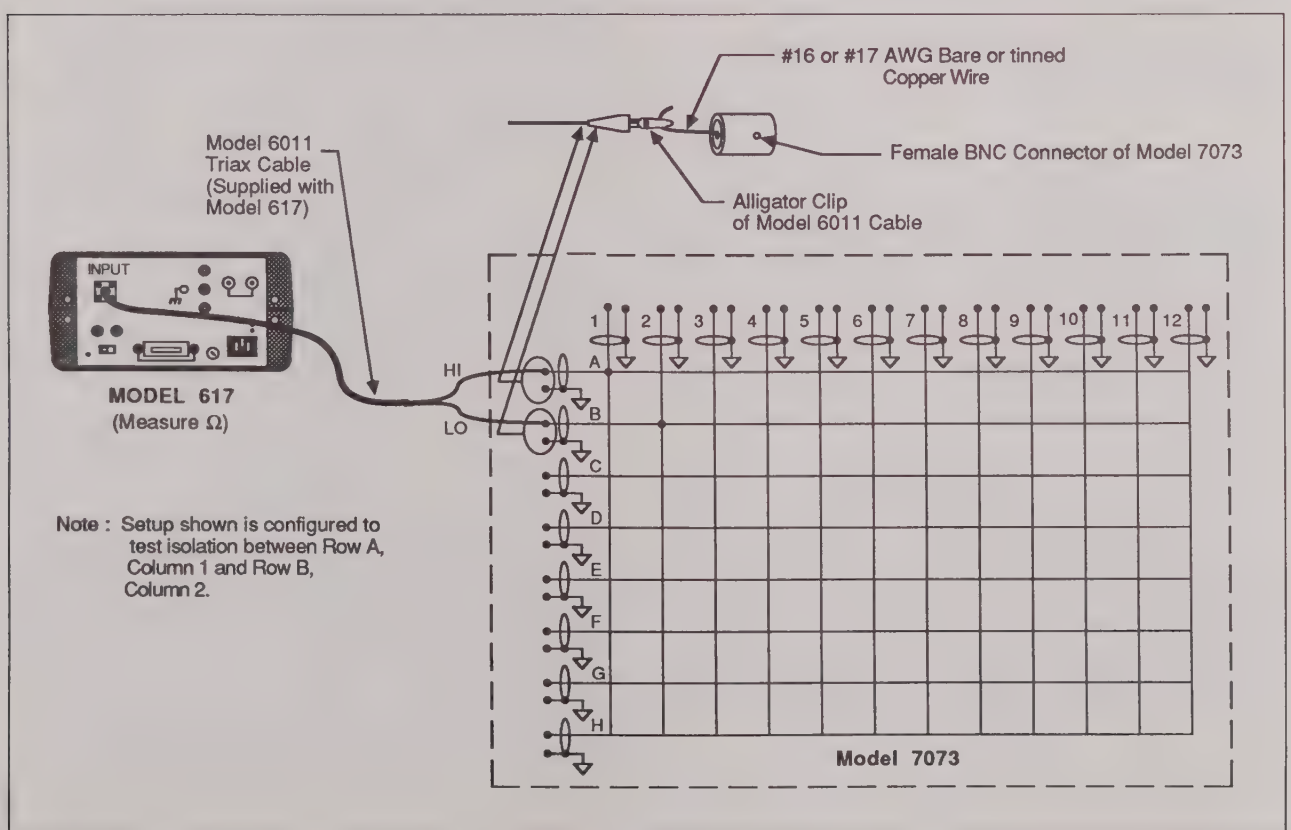


Figure 4-5. Path Isolation Testing

Table 4-2. Path Isolation Tests

Test No.	Path Isolation	Test Equipment Location	Crosspoints Closed
1	Row A, COL 1 to Row B, COL 2	Row A and Row B	A1 and B2
2	Row B, COL 2 to Row C, COL 3	Row B and Row C	B2 and C3
3	Row C, COL 3 to Row D, COL 4	Row C and Row D	C3 and D4
4	Row D, COL 4 to Row E, COL 5	Row D and Row E	D4 and E5
5	Row E, COL 5 to Row F, COL 6	Row E and Row F	E5 and F6
6	Row F, COL 6 to Row G, COL 7	Row F and Row G	F6 and G7
7	Row G, COL 7 to Row H, COL 8	Row G and Row H	G7 and H8
8	Row G, COL 8 to Row H, COL 9	Row G and Row H	G8 and H9
9	Row G, COL 9 to Row H, COL 10	Row G and Row H	G9 and H10
10	Row G, COL 10 to Row H, COL 11	Row G and Row H	G10 and H11
11	Row G, COL 11 to Row H, COL 12	Row G and Row H	G11 and H12

4.4.7 Input Isolation Tests

These tests check the leakage resistance (isolation) between high (HI) and low (Chassis) of every row and column.

Referring to Figure 4-6, perform the following procedure to check input isolation:

1. Turn the Model 707 off if it is on.
2. Install the matrix card in slot 1 of the Model 707.
3. On the Model 617, select the 2kΩ range, and enable zero check and zero correct in that order. Leave zero correct enabled for the entire procedure.
4. Connect the Model 617 to the matrix card as shown in Figure 4-6.
5. On the Model 617, select the 1GΩ range.
6. Turn on the Model 707, but do not program any crosspoints to close. All crosspoints must be open.
7. On the Model 617, disable zero check.
8. After allowing the reading on the Model 617 to settle, verify that it is >1GΩ. This measurement is the leakage resistance (isolation) of ROW A.
9. Place the Model 617 in zero check.
10. Program the Model 707 to close crosspoint A1.
11. On the Model 617, disable zero check.
12. After allowing the reading on the Model 617 to settle, verify that it is also >1GΩ. This measurement checks the isolation of COLUMN 1.
13. Using Table 4-3 as a guide, repeat the basic procedure of steps 9 through 12 for the rest of the columns and rows (test numbers 3 through 20 of the table).

Table 4-3. Input Isolation Test

Test No.	Input Isolation	Crosspoints Closed
1	ROW A	None
2	COLUMN 1	A1
3	COLUMN 2	A2
4	COLUMN 3	A3
5	COLUMN 4	A4
6	COLUMN 5	A5
7	COLUMN 6	A6
8	COLUMN 7	A7
9	COLUMN 8	A8
10	COLUMN 9	A9
11	COLUMN 10	A10
12	COLUMN 11	A11
13	COLUMN 12	A12
14	ROW B	A1 and B1
15	ROW C	A1 and C1
16	ROW D	A1 and D1
17	ROW E	A1 and E1
18	ROW F	A1 and F1
19	ROW G	A1 and G1
20	ROW H	A1 and H1

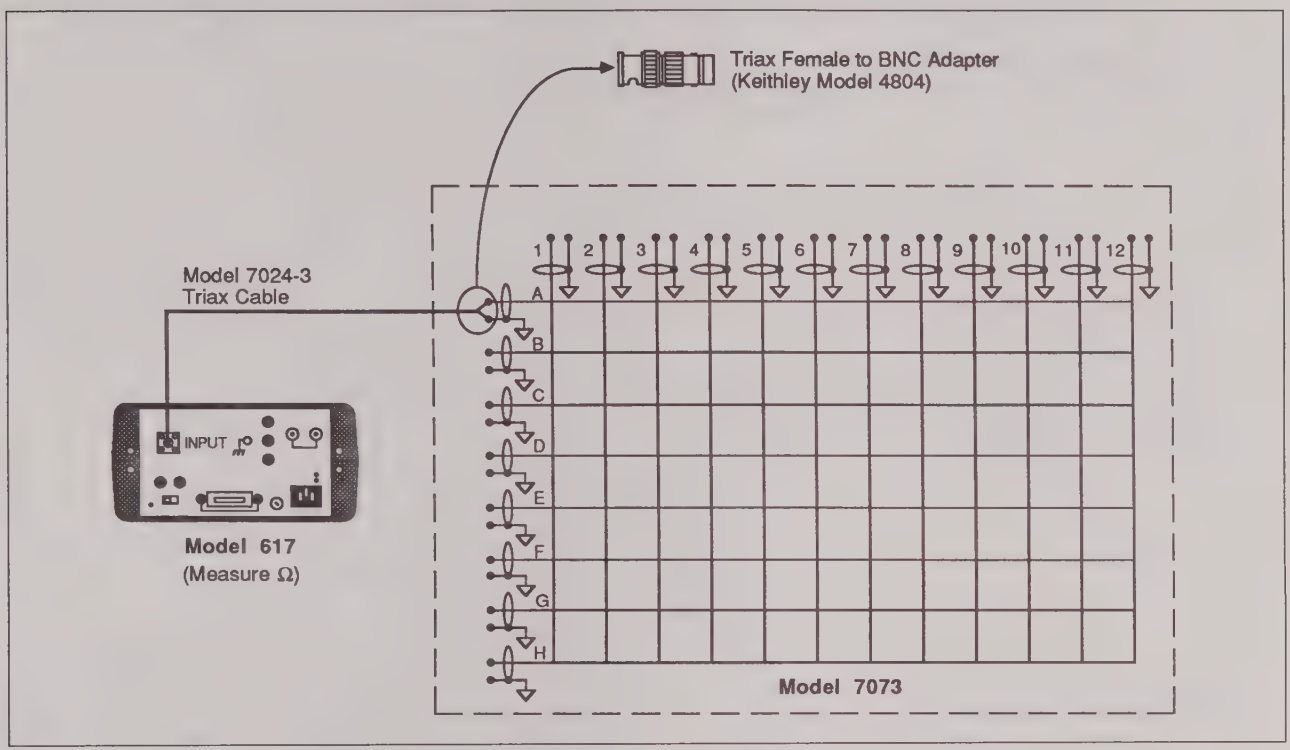


Figure 4-6. Input Isolation Testing

4.5 PRINCIPLES OF OPERATION

The paragraphs below discuss the basic operating principles for the Model 7073 and can be used as an aid in troubleshooting the matrix card. The schematic drawing of the matrix card is shown on drawing number 7073-106, located at the end of Section 5.

4.5.1 Card Identification

Identification coding and a matrix configuration table is stored in an erasable programmable read-only memory (EPROM). This information is sent to the Model 707 so that it "knows" which type of matrix card is installed in that particular mainframe slot. This enables the Model 707 to send valid configuration data to the matrix card.

On power-up, control line $\overline{\text{CARDSEL}}$ goes low turning on the EPROM (U27). That control line, as well as the other control lines from the Model 707, is buffered by U1. Lines CLK, $\overline{\text{NEXT ADDR}}$ and CLR ADDR along with counter U14 control the task of loading data from the EPROM into the parallel to serial shift register (U28). Data is clocked from U27 to the Model 707 via the IDDATA line by the CLK control line. A timing diagram for the transfer sequence of each byte of identification data is shown in Figure 4-7.

4.5.2 Switching Circuitry

Matrix configuration data is sent from the Model 707 via the RELAY DATA control line and serially loaded into the 12 shift registers (U30 through U41). The matrix card relays configure accordingly when the registers receive the STROBE signal from the Model 707. A relay is energized when a register output is low (connected to digital common).

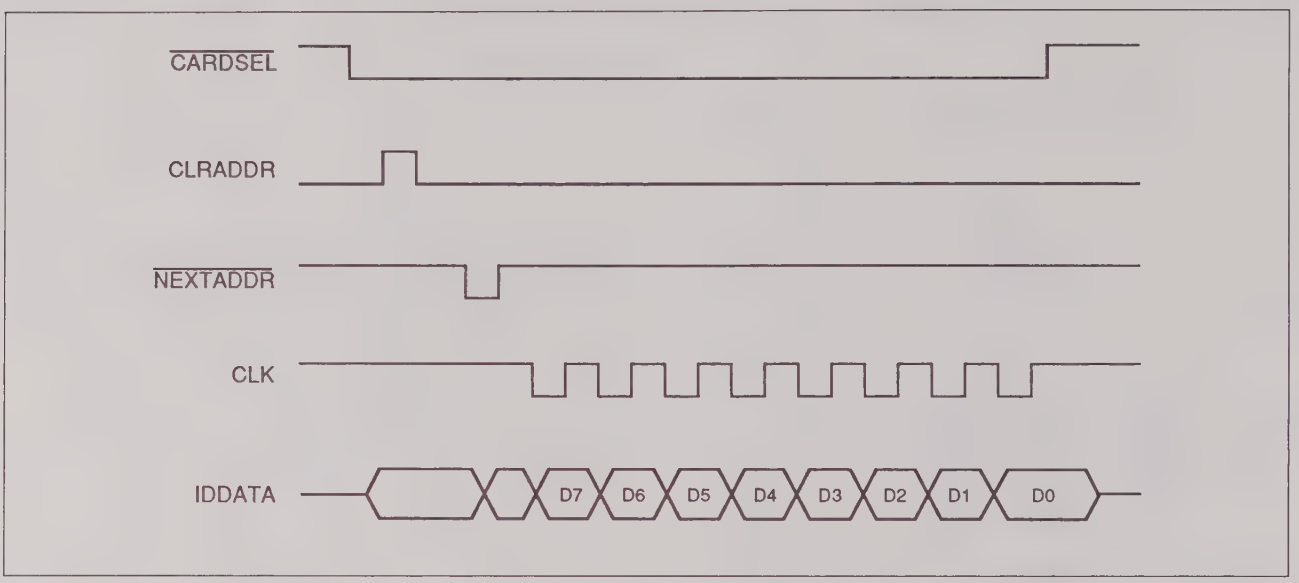


Figure 4-7. IDDATA Timing Diagram

4.5.3 Power-Up Safeguard

To prevent relays from inadvertantly energizing and causing possible damage during power up, a safeguard circuit has been incorporated into the design. The protection circuit is comprised of a dual NAND gate (U29) and an RC network (R1, C20 and CR1). The time constant of the RC network keeps the the output of the NAND gate high during the power-up sequence. This high signal is applied to the $\overline{OEN}$ input of the shift registers keeping the relays de-energized. After the capacitor of the RC network charges, the falling edge of the first STROBE signal will then force the output of the NAND gate low allowing configured relays to energize.

4.6 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS and other high-impedance devices are subject to possible static discharge damage because of the high-impedance levels involved. The following precautions pertain specifically to static-sensitive devices. However, since many devices in the Model 7073 are static-sensitive, it is recommended that they all be treated as static-sensitive.

1. Such devices should be transported and handled only in containers specially designed to prevent or dissipate static build-up. Typically, these devices will be received in anti-static containers made of plastic or foam. Keep these parts in their original containers until ready for installation.
2. Revove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap while working with these devices.
3. Handle the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the device is to be inserted must first be grounded to the bench or table.
5. Use only anti-static type de-soldering tools and grounded-tip soldering irons.

4.7 TROUBLESHOOTING

The Keithley Model 7070 Universal Adapter card is an extender card that allows the card to operate outside of the Model 707 so that it can be troubleshooted.

4.7.1 Recommended Equipment

Table 4-4 summarizes the equipment necessary for general troubleshooting.

Table 4-4. Recommended Troubleshooting Equipment

Description	Application
DMM (Keithley 196)	Measure DC voltage
Dual-trace, triggered sweep oscilloscope, DC to 50MHz	Check clock and logic pulses
Extender Card (Keithley 7070)	Allow circuit access

4.7.2 Troubleshooting Procedure

To gain access to individual circuit components, remove the circuit board shield. The shield is secured to the board with seven screws.

Table 4-5 outlines the troubleshooting procedure for the matrix card.

CAUTION

Contamination will degrade the performance of the matrix card. To avoid contamination, always grasp the card by the handle and side edges. Do not touch the edge connectors of the card, and do not touch the board surfaces or components.

Table 4-5. Troubleshooting Summary*

Step	Item/Component	Comment	Required Condition
1	TP1	+6V supply	+6VDC
2	TP3	+5V supply	+5VDC
3	TP5	CLR ADDR line**	High logic pulse at beginning of each card identification byte transfer
5	TP4	$\overline{\text{NEXT ADDR}}$ line**	Low logic pulse after CLR ADDR pulse.
6	TP9	CLK line	Hz clock
7	TP6	IDDATA line**	Card identification logic pulse train (on power-up).
8	TP10	Power-up safeguard	Remains high during power-up
9	TP8	RELAY DATA line	Logic pulse train to load relay configuration resistors
10	TP7	STROBE line	High logic pulse to strobe relay configuration registers.
11	U30 thru U41, pins 11 thru 18	Relay Drivers	+6V for open crosspoints ≈0V for closed crosspoints

*All measurements referenced to digital common (TP2)
**See Figure 4-9

SECTION 5
Replaceable Parts

5.1 INTRODUCTION

This section contains a list of replaceable electrical and mechanical parts for the Model 7073, as well as a component layout drawing and schematic diagram of the matrix card.

5.2 PARTS LISTS

Electrical parts are listed in order of circuit designation in Table 5-1. Table 5-2 summarizes miscellaneous parts.

5.3 ORDERING INFORMATION

To place a parts order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see the inside front cover for addresses). When ordering parts, be sure to include the following information:

1. Matrix card model number (7073)
2. Card serial number
3. Part description
4. Circuit description, if applicable
5. Keithley part number

5.4 FACTORY SERVICE

If the matrix card is to be returned to Keithley Instruments for repair, perform the following:

1. Complete the service form at the back of this manual and include it with the card.
2. Carefully pack the card in the original packing carton.
3. Write ATTENTION REPAIR DEPT on the shipping label.

Note: It is not necessary to return the matrix mainframe with the card.

5.5 COMPONENT LAYOUT AND SCHEMATIC DIAGRAM

Figure 5-1 shows a component layout of the Model 7073, while Figure 5-2 shows a schematic diagram.

TABLE 5-1. MODEL 7073, PARTS LIST

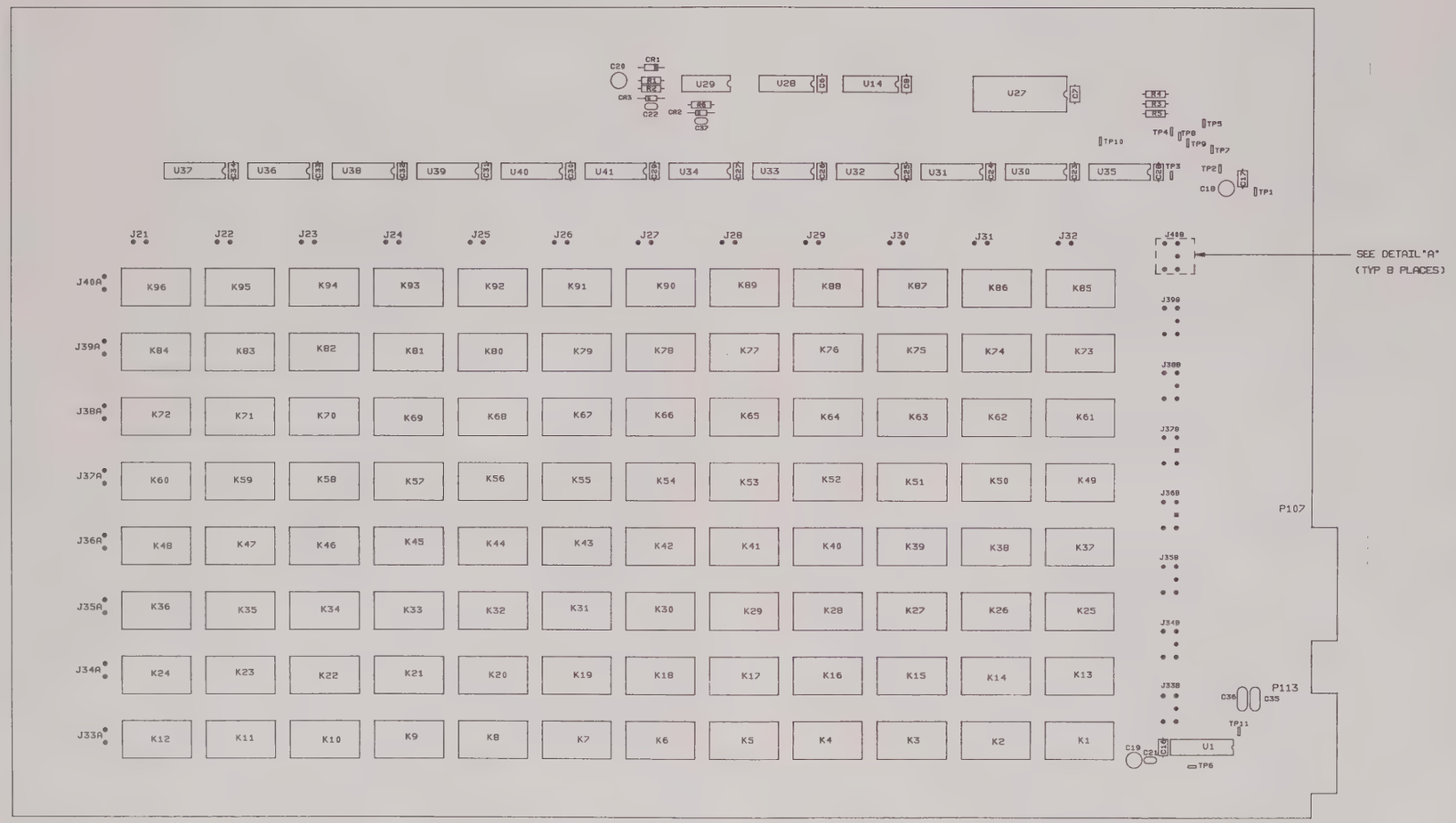
CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART NO.
C18..C20	CAP,10uF,-20+100%,25V,ALUM ELEC	C-314-10
C21,C22,C37	CAP,.01uF,20%,50V,CERAMIC	C-237-.01
C23..C34		
C35,C36	CAP,270pF,20%,100V,	C-386-270P
C6..C8,C16,C17,	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
CR1	DIODE,SILICON,1N4148 (DO-35)	RF-28
CR2,CR3	DIODE,SCHOTTKY BARRIER,IN5711	RF-69
J1..J12	CABLE ASS'Y	CA-53-1
J13..J20	CABLE ASS'Y	CA-53-2
J21...J40	CONTACT PIN	24249
K1..K96	RELAY,(4PST)	RL-104
R1	RES,47K,5%,1/4W,COMPOSITION OR FILM	R-76-47K
R2	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
R3	RES,11K,5%,1/4W,COMPOSITION OR FILM	R-76-11K
R4	RES,910,5%,1/4W,COMPOSITION OR FILM	R-76-910
R6	RES,220,5%,1/4W,COMPOSITION OR FILM	R-76-220
TP1..TP11	CONN,TEST POINT	CS-553
U1	IC,OCTAL BUFFER/LINE DRIVER,74HCT244	IC-483
U14	IC,12 STAGE BINARY COUNTER,74HCT4040	IC-545
U27	PROGRAM	7073-800
U28	IC,8 BIT PARALLEL TO SERIAL,74HCT165	IC-548
U29	IC,QUAD 2 INPUT NAND,74HCT00	IC-399
U30..U41	IC,8-BIT SERIAL-IN/LTCH DRIVE,UCN-5841A	IC-536

TABLE 5-2. MODEL 7073, MISCELLANEOUS PARTS LIST

QTY.	DESCRIPTION	KEITHLEY PART NO.
8	BACKPLANE DISCONNECT JUMPER	J-10-5
1	HANDLE	HH-33-1
1	SHIELD (COMPONENT SIDE OF PC-BOARD	7073-304
1	SHIELD (TRACE SIDE OF PC-BOARD)	7071-311
1	SOCKET (FOR U27)	SO-69
1	SHIELD, REAR	7071-311
8	STANDOFFS	7071-310

D7073-100 REV

LTR.	ECO NO.	REVISION	ENG.	DATE
B	12320	RELEASED	SZ	8-24-87
C	12422	REVISED	SZ	11-12-87
D	12554	REVISED		12-29-87



NOTE:
FOR COMPONENT INFORMATION,
REFER TO BILL OF MATERIAL
7073-000-00.

7073					
MODEL	NEXT ASSEMBLY	QTY.			
USED ON					

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 8-22-87	SCALE 1:1	TITLE COMPONENT LAYOUT, COAX CARD
KEITHLEY KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139	XX=±.015 ANG.=±1°	DRN. CB	ENG. APPR.	
	XXX=±.005 FRAC.=±1/64	MATERIAL		D NO. 7073-100
	SURFACE MAX. 63	FINISH		

Figure 5-1. Model 7073 Component Location Drawing, Dwg. No. 7073-100

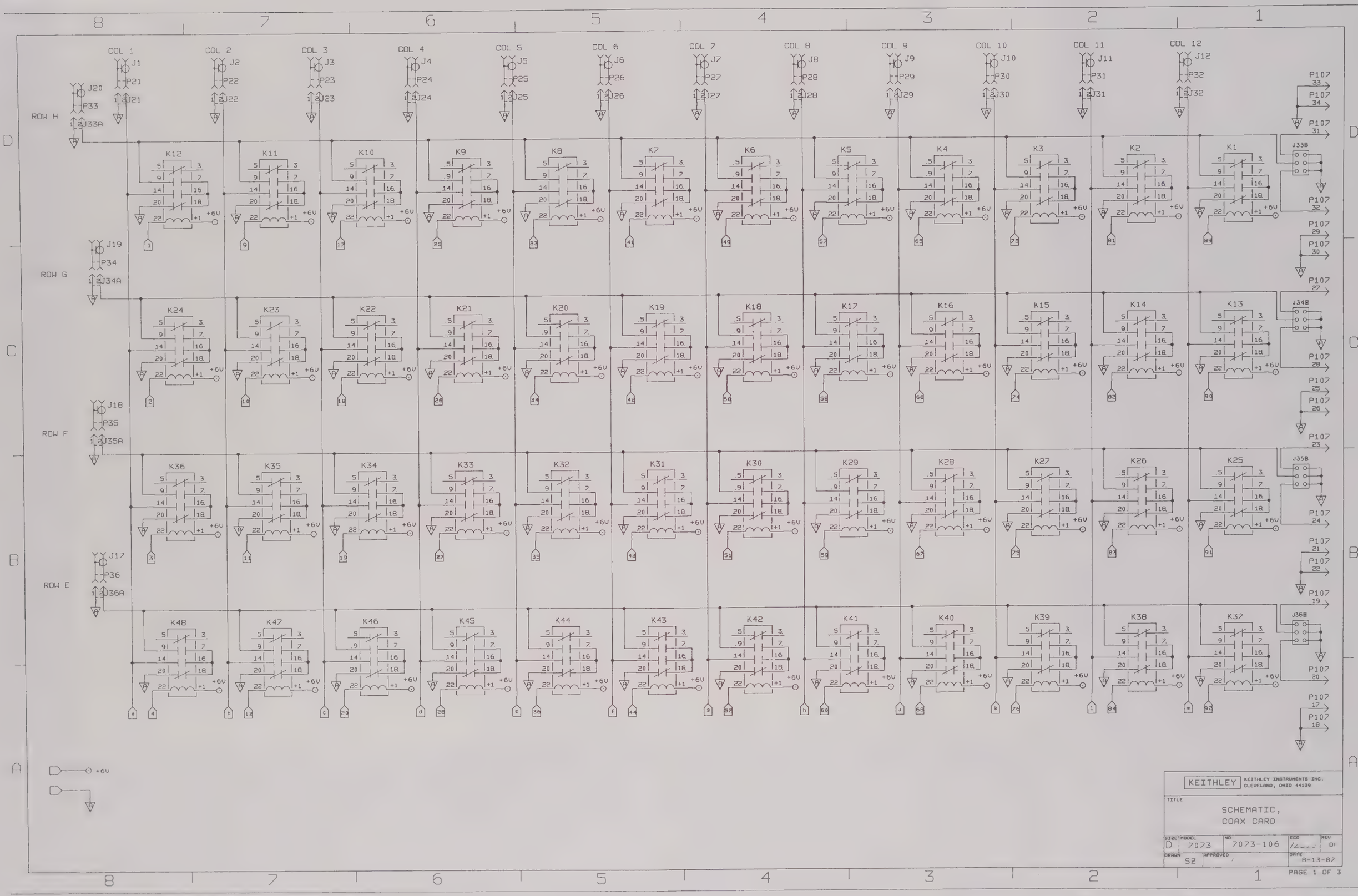



Figure 5-2. Model 7073 Schematic Diagram, Dwg. No. 7073-106 (sheet 1 of 3)

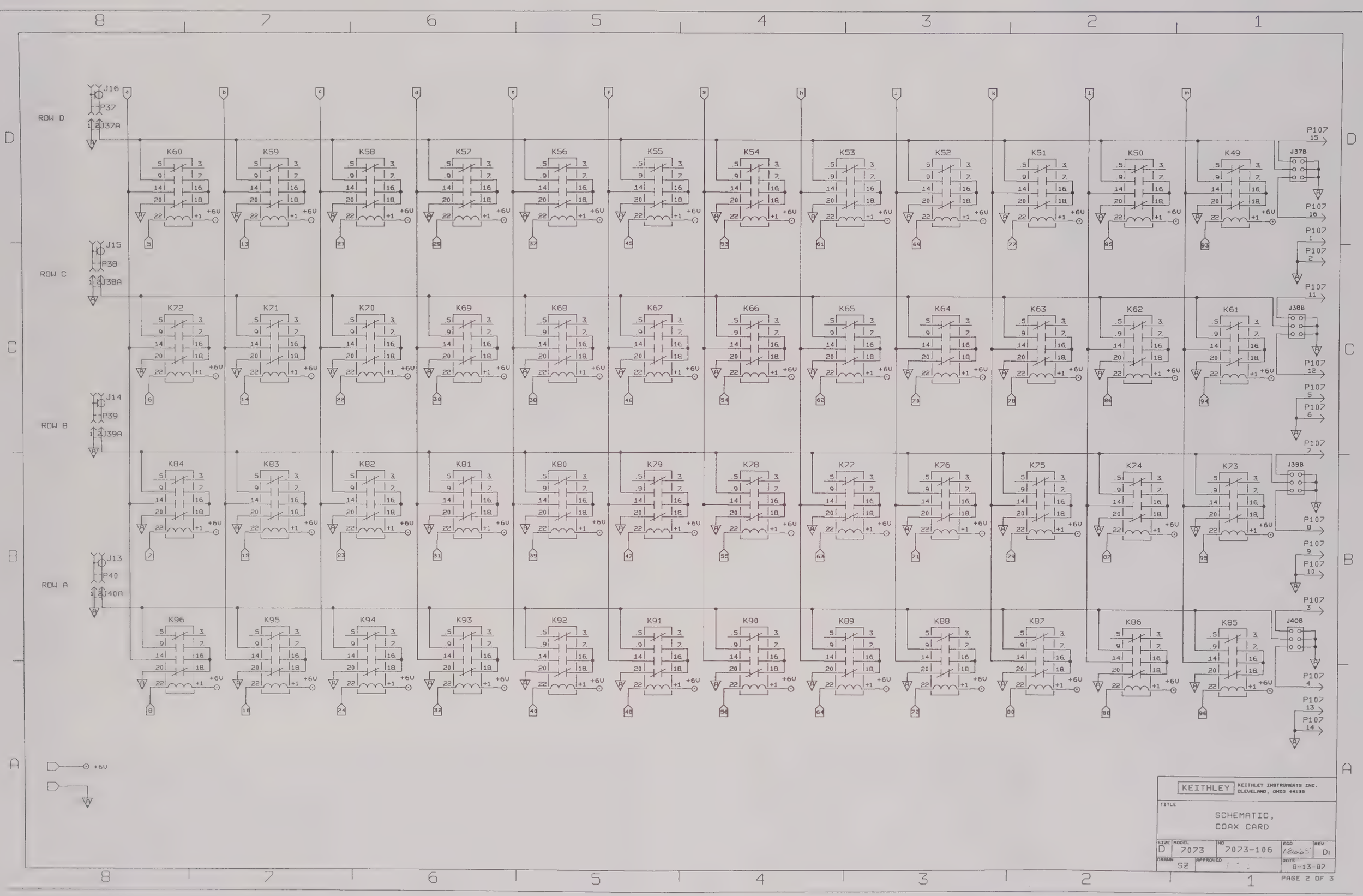


Figure 5-2. Model 7073 Schematic Diagram, Dwg. No. 7073-106 (sheet 2 of 3)

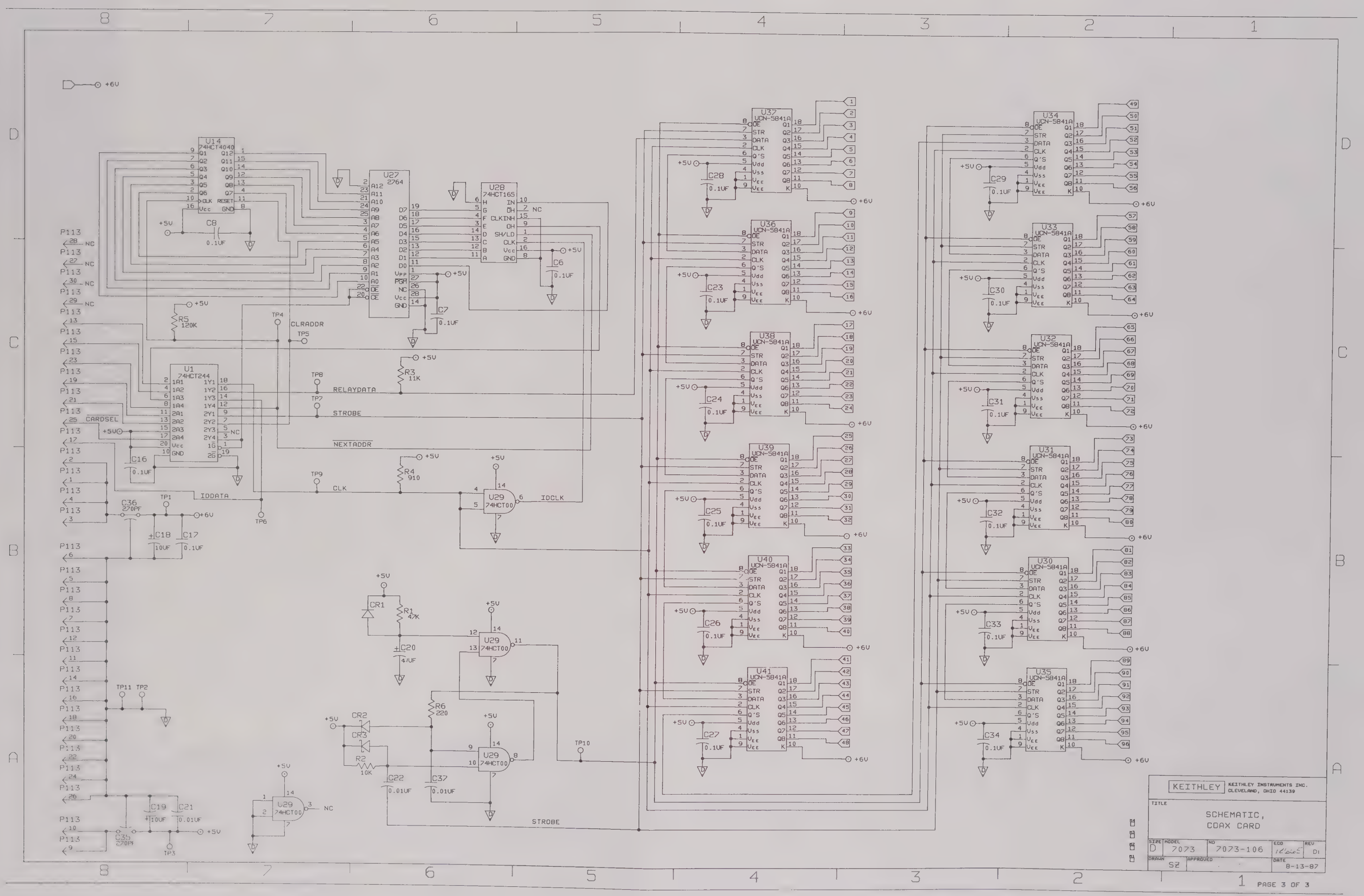


Figure 5-2. Model 7073 Schematic Diagram, Dwg. No. 7073-106 (sheet 3 of 3)

KEITHLEY

SERVICE FORM

Model No. _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

Name _____ **Phone** _____

Company _____

Address _____

City _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.) _____

What power line voltage is used? _____ Variation? _____

Frequency? _____ Ambient Temperature? _____ °F.

Variation? _____ °F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

KEITHLEY

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28775 Aurora Road / Cleveland, Ohio 44139 / U.S.A. / (216) 248-0400 / Telex: 98-5469

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GREAT BRITAIN: **Keithley Instruments, Ltd.** / 1 Boulton Road / Reading, Berkshire RG 2 ONL / 0734-861287// Telex: 847 047 / Telefax: 0734-863665
FRANCE: **Keithley Instruments SARL** / 3 Allee du 10 Rue Ambroise Croizat / B.P. 60 / 91121 Palaiseau/Cedex / 1-6-0115 155 / Telex: 600 933 / Telefax: 1-6-0117726
NETHERLANDS: **Keithley Instruments BV** / Avelingen West 49 / 4202 MS Gorinchem / P.O. Box 559 / 4200 AN Gorinchem / 01830-35333 / Telex: 24 684 / Telefax: 01830-30821
SWITZERLAND: **Keithley Instruments SA** / Kriesbachstr. 4 / 8600 Dübendorf / 01-821-9444 / Telex: 828 472 / Telefax: 0222-315366
AUSTRIA: **Keithley Instruments GesmbH** / Döblinger Haupstr. 32 / 1190 Wien / 0222-314-289 / Telex: 134 500 / Telefax: 0222-315366
ITALY: **Keithley Instruments SRL** / Viale S. Gimignano 4/A / 20146 Milano / 02-4120360 or 02-415640 / Telefax: 02-4121249

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